TALC DEPOSITS OF THE SOUTHERN DEATH VALLEY-KINGSTON RANGE REGION, CALIFORNIA

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CONTENTS

Illustrations

Illustrations (continued)

ABSTRACT

In eastern California, a talc-bearing belt extends for about seventy-five miles from the southern Panamint Range eastward to the Kingston Range. It contains 29 talc mines which, through 1959, had yielded about 1,200,000 tons of commercial material. The deposits are confined to the Crystal Spring Formation, the lowest formation of the later Precambrian Pahrump Group. The formation, ordinarily about 4000 feet thick, consists of a lower part composed mostly of quartzite and shale, a middle part of dolomite, cherty dolomite, limestone and massive chert and an upper part of interbedded quartzite, shale and dolomite. The formation also contains sills of diabase which are especially persistent along the lower and upper margins of the middle, carbonate-bearing part of the formation and which also are of later Precambrian age.

Along or near many of the diabase contacts, and in septa within the sills, the carbonate strata have been silicated. All of the commercial talc mined has been obtained from a zone of silication at the base of the massive carbonate member and in contact with or near the lower sill. The material of commercial grade is a fine-grained white rock composed mostly of talc and/or tremolite. The more productive bodies show average widths of 10 to 25 feet and range in length from 1000 feet to a mile or more.

Most occurrences of the zone lie immediately above the sill; some are separated from the sill by a layer of quartzite and/or shale; others occur in septa within the sill; and still others lie beneath the sill. A few bodies of talc-bearing rock extend with fingerlike cross sections into the carbonate strata from the borders of diabase dikes. Where it lies along the upper margin of the sill, the zone commonly consists of a lower, thinly laminated layer composed predominantly of either talc or tremolite, a middle layer of talc schist, and a brown outer, alkali-rich layer with abundant feldspar and mica. Alteration zones composed of a green tremolitic rock, ordinarily rich in alkali feldspar, occur at various stratigraphic positions within the carbonate member.

Most of the bodies of commercial talc-tremolitic rock are replacements of dolomite or cherty dolomite but some appear to have formed at the expense of limestone. All represent enrichment in MgO; the formation of some of the bodies has required the addition of silica. As the replacement does not appear to have involved loss of volume, much of the MgO probably is also additive. The localization of the most persistent, most intensively altered and most hydrous zone of silication seems best attributed to (1) a greater abundance of ground water, in the poorly consolidated clastic sediments below the base of the carbonate member than within the member, and (2) perhaps also to a greater abundance of silica available in the underlying strata and in the lower part of the carbonate member than in the upper part. The source of the additive MgO is not obvious. As many of the diabase-dolomite contacts high in the member are barren of silication or nearly so, and as the diabase next to the silicated zone, at least locally, appears to have been enriched in MgO, the diabase probably was not a source of MgO. Ground water in the original strata, although apparently magnesian, probably could not have yielded enough MgO to satisfy the larger bodies of talc. As no dolomites or other highly magnesian rocks were observed lower in the section, derivation from lower strata is unlikely. Although no evidence of dedolomitization of the overlying strata was noted, they may have yielded MgO through considerable thicknesses along the thermal gradient established during the intrusion of the diabase. Evidence of a light sedimentary load at the time of alteration and a persistent calcite-tremolite association in the altered rock suggest temperatures of less than 650°C and pressures in the range of 300 to 600 atmospheres.

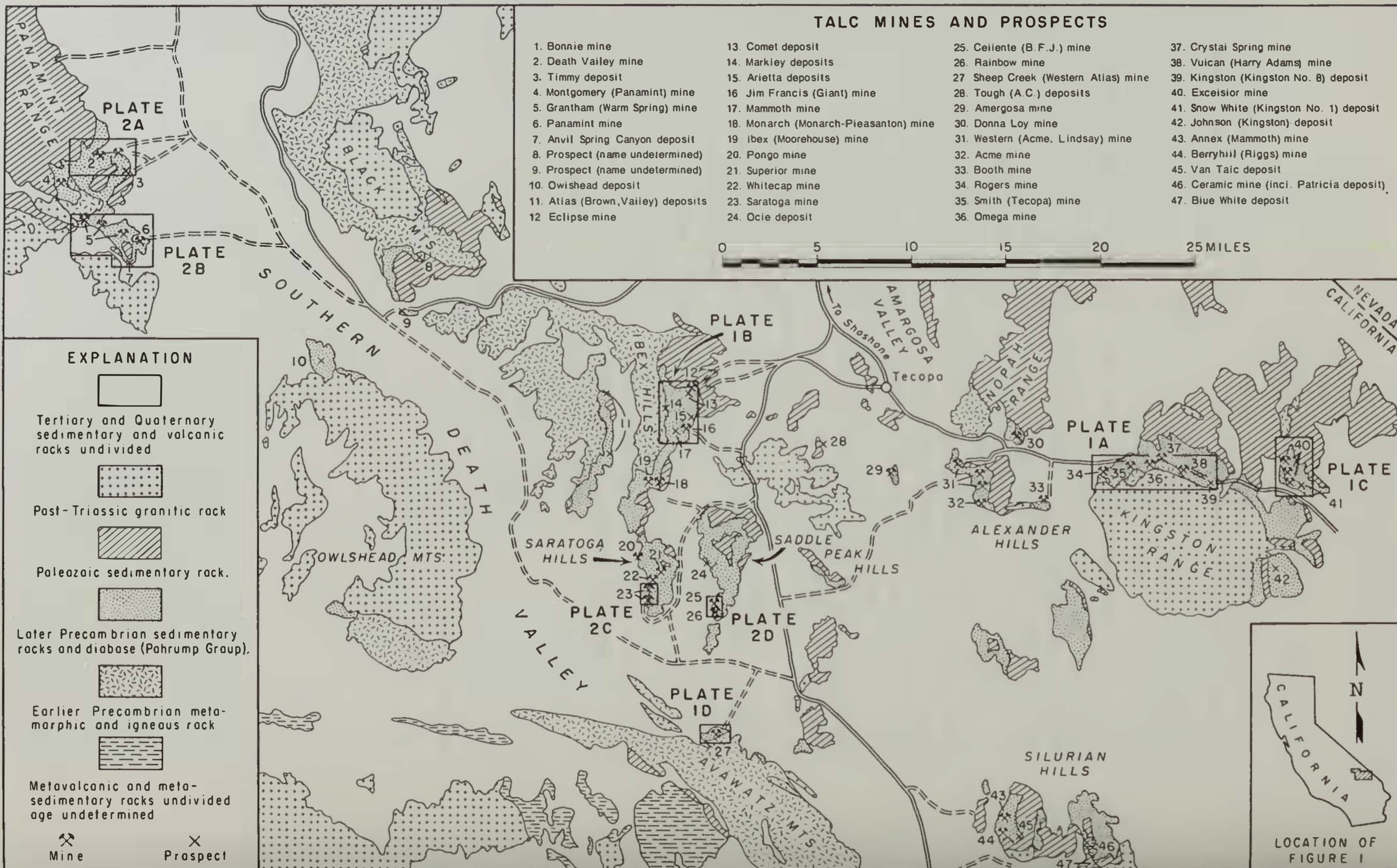

Figure 1. Map of southern Death Valley-Kingston Range region showing the distribution of major rock units and the location of talc mines and prospects. ***Modified from Wright (1957).***

ALC DEPOSITS OF THE SOUTHERN DEATH VALLEY–
:INGSTON RANGE REGION, CALIFORNIA

LAUREN A. WRIGHT

INTRODUCTION

In the desert of eastern California, throughout a gion that embraces the southern part of the Panamint ange, the Kingston Range and the intervening parts Death Valley and Amargosa Valley, are numerous, ɜologically similar talc deposits. For many years these ɔllectively have been one of the principal sources commercial talc in the United States. From 1910 ırough 1959, twenty-nine mines have yielded a total about 1,200,000 short tons of commercial talc. In ɔ59 about 100,000 tons was produced from 17 prop-·ties. Although most of this material consisted pre-ominantly of the mineral talc, some of it was com-osed largely of tremolite; but all was recorded as talc" in the commercial sense of the term.

In the early 1900's, although prospectors had ıoroughly searched the Death Valley region for de-osits of valuable metallic minerals and borates, the ılc bodies had attracted little or no attention. Even ad they been recognized as being of potential value, ıeir remoteness and the very small market for com-ıercial talc at that time would have discouraged any-ne from attempting to mine them. Today, however, ıe talc deposits support all but a small part of the ıining activity in the Death Valley region and stand econd to the tourist trade as a source of income for ıe region's residents. This growth is attributable ıostly to the development of industrial uses for talc, articularly in the wall tile and paint trades, and to he increased demand for these materials on the Pacific Coast of the United States.

The deposits of this group are restricted geograph-ically because they occur in a single geologic unit—he Crystal Spring Formation of later Precambrian age —the known exposures of which are confined to the outhern Death Valley-Kingston Range region. The alc-bearing belt, although irregular in outline, trends ıorth-northwestward, is about 75 miles long and is 5 miles in average width (fig. 1). From west to east t extends from the southern part of the Panamint Range, across southern Death Valley, the Black Mountains, Amargosa Valley, and the hills at the outhern end of the Nopah Range, to the Kingston Range and Silurian Hills. Other talc deposits occur n the Silver Lake-Yucca Grove area (Wright and others, 1953; Wright, 1954) east and southeast of the Silurian Hills, but these appear to be genetically un-elated to those of the Crystal Spring Formation.

Most of the talc mines in the southern Death Valley-Kingston Range region are clustered in six areas where exposures of the Crystal Spring Formation are particularly extensive: 1) the Warm Spring Canyon-Galena Canyon area on the southeastern slope of the Panamint Range; 2) the Ibex Hills, Saratoga Hills and Saddle Peak Hills at the southern end of the Black Mountains; 3) the Alexander Hills at the southern end of the Nopah Range; 4) the northwestern part of the Kingston Range; 5) the eastern part of the Kingston Range; and 6) the Silurian Hills. Of the several deposits that lie outside of these areas, only the Sheep Creek deposit at the north base of the Avawatz Mountains has been formally mined in recent years.

Physical and Cultural Features of the Talc-Bearing Region

North- to northwest-trending mountains and ridges dominate the region of the Amargosa and Death Valleys, and most of them are sufficiently steep and free of overburden to form nearly continuous exposures of bed rock. They consist predominantly of hard rocks, of many types and ages, whereas the intervening valleys in general are underlain by soft sedimentary rocks of Tertiary and Quaternary age (Noble and Wright, 1954). The talc-bearing areas can be visualized as parts of resistant "islands" in a sea of softer and generally younger rocks (fig. 1), so that in many places talc-bearing zones extend from surface exposures for undetermined distances beneath a cover of younger rocks.

The talc deposits range in altitude from approximately 300 feet near Saratoga Spring at the southern end of Death Valley to nearly 5000 feet in the Kingston Range. Rainfall in the region ranges from an annual average of less than 3 inches on the floor of Death Valley to somewhat more than 6 inches in the higher parts of the Kingston Range. Most of the mines are completely dry, and in only one of them—the Smith on the western slope of the Kingston Range —have water seepages been a serious hindrance to mining.

Springs are few, and widely scattered throughout the talc-bearing region, but several provide water for the talc mining. Among these are Warm Spring and Galena Spring in the Panamint Mountains, Ibex Spring at the southeast base of the Ibex Hills, Saratoga Spring at the southwest end of the Saratoga Hills, Crystal Spring, Beck Spring and Horse Thief Spring in the Kingston Range, and Sheep Spring in the northern part of the Avawatz Mountains.

The central part of the talc-bearing belt is crossed by State Highway 127, which is paved and it extends north-northwestward from Baker across the southern end of Death Valley and thence along the Amargosa Valley through Shoshone and Death Valley Junction (fig. 1) and to Nevada.

State Highway 127 is joined, in the vicinity of Shoshone, by another paved highway which extends west-southwestward across the southern end of the Black Mountains to the vicinity of the old Ashford (gold) millsite and thence north-northwestward, along the east side of Death Valley to Furnace Creek Ranch. The segment of southern Death Valley that extends from the crossing of Highway 127 to the Ashford millsite area is followed by an unpaved, but generally well-graded highway along which talc from the Panamint Range is hauled. Access to various canyons on the east slope of the Panamint Range is obtained from a graded road along the west side of Death Valley. This road parallels the paved road to the east and connects with it near the millsite and at a point about 6 miles south of Furnace Creek Ranch.

Side roads from the main highways lead to most of the talc-bearing localities and all of the talc mines. The access roads to the active mines and several of the inactive mines generally are graded and well-kept. Others are unimproved and should be used only by persons experienced in desert driving and preferably with truck-type or four-wheel drive vehicles.

Talc mined in the region formerly was shipped from various points on the Tonopah and Tidewater Railroad which was approximately parallel to Highway 127. Since 1941, when the rails were removed, talc has been trucked to Dunn and Field sidings which are on the Union Pacific Railroad and about 25 miles west of Baker. These sidings are about 90 to 95 miles by road from Shoshone, and 150 to 155 miles by rail from Los Angeles.

Although many thousands of tourists traverse the region of southern Death Valley and southern Amargosa Valley each year, only about 300 persons live there permanently. These reside mostly in the settlements of Shoshone and Tecopa, both in the Amargosa Valley, and at least one-third of them are employees of talc companies or their families.

Acknowledgements

Many persons, including staff members of talc mining companies, visiting geologists, various of the writer's colleagues in the Division of Mines and Geology, and his faculty advisors and fellow students at the California Institute of Technology, contributed data to this report or have discussed related problems with the author. Of those that can be individually acknowledged in these few sentences, especial thanks are extended to Dr. Olaf P. Jenkins, Chief of the Division of Mines and Geology during most of the project and to his successor Dr. Ian Campbell who supervised the final stages and who earlier had served as the writer's advisor when many of the data were included in a thesis at the California Institute of Technology.

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GEOLOGIC ENVIRONMENT OF THE TALC DEPOSITS

Introduction

The Crystal Spring Formation, in which the talc mineralization has been localized, is the lowest and most extensively exposed of the three formations that compose the Pahrump Group of later Precambrian age. This formation and the two successively higher units—the Beck Spring Dolomite and the Kingston Peak Formation—are sufficiently distinctive in lithology to be easily recognized throughout most of the talc-bearing belt, even in areas of great structural complexity.

PREVIOUS INVESTIGATIONS OF THE PAHRUMP GROUP AND TALC DEPOSITS

In the mid-1870's G. K. Gilbert (1875, pp. 34, 170), upon observing the geological features of the Saratoga Spring area along the southeast margin of Death Valley, was the first to describe exposures of the marine sedimentary and intrusive diabasic rocks that were to be included in the Pahrump Group. Gilbert noted their unfossiliferous character, but did not assign an age. In 1902, the same exposures were briefly mentioned by M. R. Campbell (1902, p. 14) who presumed the rocks to be of Cambrian or Precambrian age.

The occurrences of these rocks in the southern Death Valley area were described in a general manner by Noble (1934, pp. 173–178) and were briefly mentioned by Hazzard (1937, p. 299). Both Noble and Hazzard assigned to them a later Precambrian (Algonkian) age; but they remained unnamed until 1940, when Hewett (1940, pp. 239–240) proposed the name "Pahrump series", and recognized the three-fold division. Representative sections of these formations were later described in detail by Hewett in an account of the geology of the Ivanpah quadrangle (Hewett, 1956). Here he noted the presence of diabase sills and the existence of talc deposits near the base of the lowermost carbonate beds of the Crystal Spring Formation. He attributed the origin of the talc deposits to an alteration of carbonate beds by diabase. In 1941, many of the stratigraphic and structural features of the region of the southern Amargosa Valley, southern Black Mountains, and southern Death Valley, were described by Noble (1941, pp. 941–999) as background for a detailed account of the geology of the Virgin Spring area in the southern part of the Black Mountains. Noble also noted that the Crystal Spring Formation contains talc deposits as alterations of dolomite at the contacts of diabase intrusions.

Exposures of the Pahrump units at the southern end of the Nopah Range were briefly mentioned by Mason (1948, pp. 333–352). The Silurian Hills, which contain the southernmost of the known Pahrump occurrences, have been studied in detail by Kupfer (1954, Map Sheet 19; 1960) who applied the name "Pahrump group"—the designation used in the present paper. The stratigraphic section in the Saratoga Hills, which contains all three of the Pahrump formations, was described in 1952 (Wright, pp. 7–14) as part of a description of the Superior talc mine. In 1954, Noble and Wright (1954, pl. 7), on a compiled geologic map of the southern Death Valley region, showed the general distribution of these later Precambrian rocks. In 1954 also, the distribution of the Pahrump units in the Alexander Hills was shown in detail (Wright, 1954, Map Sheet 17).

The first published account of the talc deposits was that of Diller (1914) who in 1913 visited two deposits: the Sheep Creek deposit, at the north base of the Avawatz Mountains, and the deposit at the site of the present Western mine in the Alexander Hills. In succeeding years, notes on talc mining activities in the Death Valley region have been provided in the annual publication, Mineral Resources of the United States, and its successor the Minerals Yearbook. During the period 1919 to 1943, descriptions of the talc operations were presented in various publications of the California Division of Mines and Geology (Cloudman, H. C., and others, 1919, p. 899; Hamilton, Fletcher, 1921, pp. 300 and 367; Tucker, W. B., 1921, pp. 300, 367–370; Newman, M. A., 1923, p. 539; Sampson, R. J., 1937, pp. 269, 270; Tucker, W. B., and Sampson, R. J., 1930, pp. 323–325; 1938, p. 493; 1943, pp. 543–549; and Norman, L. A., and Stewart, R. M., 1951, pp. 123–127). The writer's investigations of the deposits and their geological setting have been carried on intermittently since 1948 and have led to the publication of general descriptions in several papers (Wright, 1950, pp. 122–128; Wright and others, 1954, pp. 63–65; Wright, 1957, pp. 623–634; and Engel and Wright, 1960, pp. 839–841).

OLDER PRECAMBRIAN ROCKS

At numerous localities, the Pahrump Group rests with depositional contact upon a complex of much older and much more highly metamorphosed rocks, generally designated as "earlier Precambrian" or "Archean". The complex consists mostly of metasedimentary rocks of which mica schist, granitic gneiss, and micaceous quartzite are the more abundant. Granitic gneiss that may be of intrusive origin is locally abundant. Migmatite, small bodies of pegmatite and veins and pods of milky quartz also are common. These rocks form a large part of the pre-Tertiary terrane of the southern Death Valley-Kingston Range region, and are commonly exposed along the lower slopes of the mountain ranges. They underlie most of the western and southern parts of the Black Mountains and provide the somber, gray exposures for which the mountains were named.

GENERAL FEATURES OF THE PAHRUMP GROUP

At many places in the southern Death Valley-Kingston Range region, rocks of the Pahrump Group are exposed in large, essentially intact fault blocks that permit a reasonably accurate measurement of stratigraphic sections. At some places, especially in the Ibex Hills and in the Virgin Spring Canyon area, they have been severely deformed (Noble, 1941; and Noble and Wright, 1954). The writer knows of only three localities where all three formations—Crystal Spring, Beck Spring Dolomite and Kingston Peak—are exposed in orderly sequence. These are the Kingston Range (Hewett, 1956), the Alexander Hills (Wright, 1954), and Saratoga Hills (Wright, 1952). In the Kingston Range, the group is as much as 5,000 feet thick (Hewett, 1956); in the Alexander Hills, it is about 8,000 feet thick (Wright, 1954); and in the Saratoga Hills, it is at least 5,500 feet thick (Wright, 1952).

The Crystal Spring Formation, to be described in greater detail in the following section, is generally 3000 to 4200 feet thick. It is by far the most extensively exposed of the three formations in the Pahrump Group. It consists characteristically of: (1) a lower part, a few hundred to 1000 feet thick, composed of quartzite and shale; (2) a middle part, a few tens of feet to a few hundred feet thick, of dolomite and/or limestone and a higher layer of massive chert; (3) an upper part, a few hundred feet thick, composed of interlayered and thinly bedded quartzite, shale and dolomite; and (4) sill-like bodies of diabase, a few hundred to 1000 or more feet in total thickness. The most persistent of the diabase bodies lies immediately below the carbonate unit in the middle of the formation.

In most of its occurrences, the Beck Spring Dolomite is a uniformly gray and massive, cliff-forming unit about 1000 feet thick. The contact between it and the underlying strata of the Crystal Spring Formation commonly is faulted, but, in most places, shows little or no angular discordance. As the diabase bodies, so abundant in the Crystal Spring Formation, were unobserved in the Beck Spring Dolomite, the contact may be a disconformity and represent an interval within which the diabase bodies were emplaced. Nowhere, however, was the Beck Spring Dolomite observed to rest with depositional contact upon diabase.

The Kingston Peak Formation, in the vicinity of its type locality in the Kingston Range (Hewett, 1956), is 1,000 to 2,000 feet thick. Here, it consists predominantly of shaly quartzite with local pebble-rich zones, and contains a middle third composed of conglomerate. The fragments in the conglomerate are poorly sorted and consist mostly of quartzite and dolomite. In the Alexander Hills (Wright, 1954), the Kingston Peak Formation is about 2,500 feet in maximum thickness and contains a lower 700 feet of quartzite and an upper 1,800 feet of conglomeratic quartzite. A similar conglomerate unit, at least 1,500 feet thick, comprises most of the Kingston Peak exposures in the Saratoga Hills (Wright, 1952). A conglomeratic unit, which is extensively exposed along the west side of the Panamint Range and well to the west and northwest of the known limits of the Crystal Spring Formation and Beck Spring Dolomite, has been correlated with the Kingston Peak Formation by Johnson (1957).

Angular unconformities between Kingston Peak strata and underlying units of the Pahrump Group have been observed in the southeastern part of the Panamint Range (Chester Wrucke, personal communication) and in the eastern part of the Kingston Range, but within the talc-bearing belt, the Kingston Peak Formation and the Beck Spring Dolomite are essentially conformable. The Pahrump fragments within the Kingston Peak conglomeratic units, therefore, seem to have been eroded from more distant areas. Of significance in the dating of the diabase bodies in the Pahrump Group is the widespread occurrence of diabase fragments in these conglomeratic units. These fragments are identical in lithology with the diabase in the intrusive bodies lower in the group and are unlike any other Precambrian rock in the region.

AGE OF THE PAHRUMP GROUP

The Pahrump Group is of Precambrian age as it is overlain unconformably by a very thick section of marine sedimentary rocks in which the lowest appearance of early Cambrian fossils is about 5000 feet stratigraphically higher than the unconformity. A later Precambrian designation is justified by the profound unconformity with which the Pahrump Group rests upon the complex of more highly metamorphosed rocks.

Sedimentary Units of the Crystal Spring Formation

Complete, or nearly complete, sections of the Crystal Spring Formation are widespread in the southern Death Valley-Kingston Range region and have been observed by the writer at numerous localities, including the area of Warm Spring and Galena Canyons of the southeastern part of the Panamint Range (pl. 2); the south wall of Ashford Canyon in the southern part of the Black Mountains; the east slope of the central part of the Ibex Hills (pl. 1B); in the Talc Hills; the west flanks of the Saratoga (pl. 2C; and Wright, 1952), Silurian, and Alexander Hills (Wright, 1954); in the west, central, and east parts of the Kingston Range (pl. 1A and B); and the lower north slope of the Avawatz Mountains (pl. 1D). All but the upper units of the formation also are exposed on the north slope of the Owlshead Mountains.

In order to record the stratigraphic position of the talc-bearing zone, sections of the Crystal Spring Formation were measured in Warm Spring Canyon, the Owlshead Mountains, the Ibex, Saratoga, and Alexander Hills, and the western and eastern part of the Kingston Range (fig. 2). The thickest of the measured sections of the Crystal Spring Formation, including both sedimentary rocks and sill-forming diabase, is in Warm Spring Canyon where about 4200 feet of these layered units is exposed. The occurrences of the Crystal Spring Formation in the Saratoga Hills and Alexander Hills are about 2100 and 3900 feet in measured thickness and apparently are complete. At Crystal Spring, the type locality in the northwestern part of the Kingston Range, about 3900 feet of layered Crystal Spring units also was measured, but at least a 500-foot thickness of quartzite has been faulted out of the lower part of the formation here (pl. 1A). Where measured in the eastern part of the Kingston Range (pl. 1C), the formation is about 3800 feet thick.

The thicknesses of the sedimentary parts of these sections are as follows: Warm Spring Canyon, 2800 feet; Saratoga Hills, 1500 feet; Alexander Hills, 3100 feet; western Kingston Range, 2300 feet (minimum); and eastern Kingston Range, 2500 feet. The formation at each of these localities shows essentially the same sequence of sedimentary units and no significant east-west changes in facies or thickness. North of a line extending south-southeastward from the Virgin Spring area in the southern Black Mountains through the central Ibex Hills and the southern Nopah Range to the eastern Kingston Range, the Crystal Spring Formation is missing, apparently cut out by an angular unconformity at the base of the Cambrian (?) Noonday Dolomite. On the west slope of the Panamint Range, the Crystal Spring Formation has been found only in isolated patches. In the two most southerly of the known occurrences of the formation—at Sheep Creek at the Avawatz Mountains and in the Silurian Hills—it shows a marked facies change, in that it contains a higher proportion of quartzite and a lower proportion of carbonate material than do the more northerly occurrences.

In most of the occurrences of the Crystal Spring Formation, the quartzite and shaly strata that compose its lower part are divisible into three units. These are here referred to as "the feldspathic quartzite member", the "purple shale member", and the "fine-grained quartzite member". As the carbonate beds in the mid-

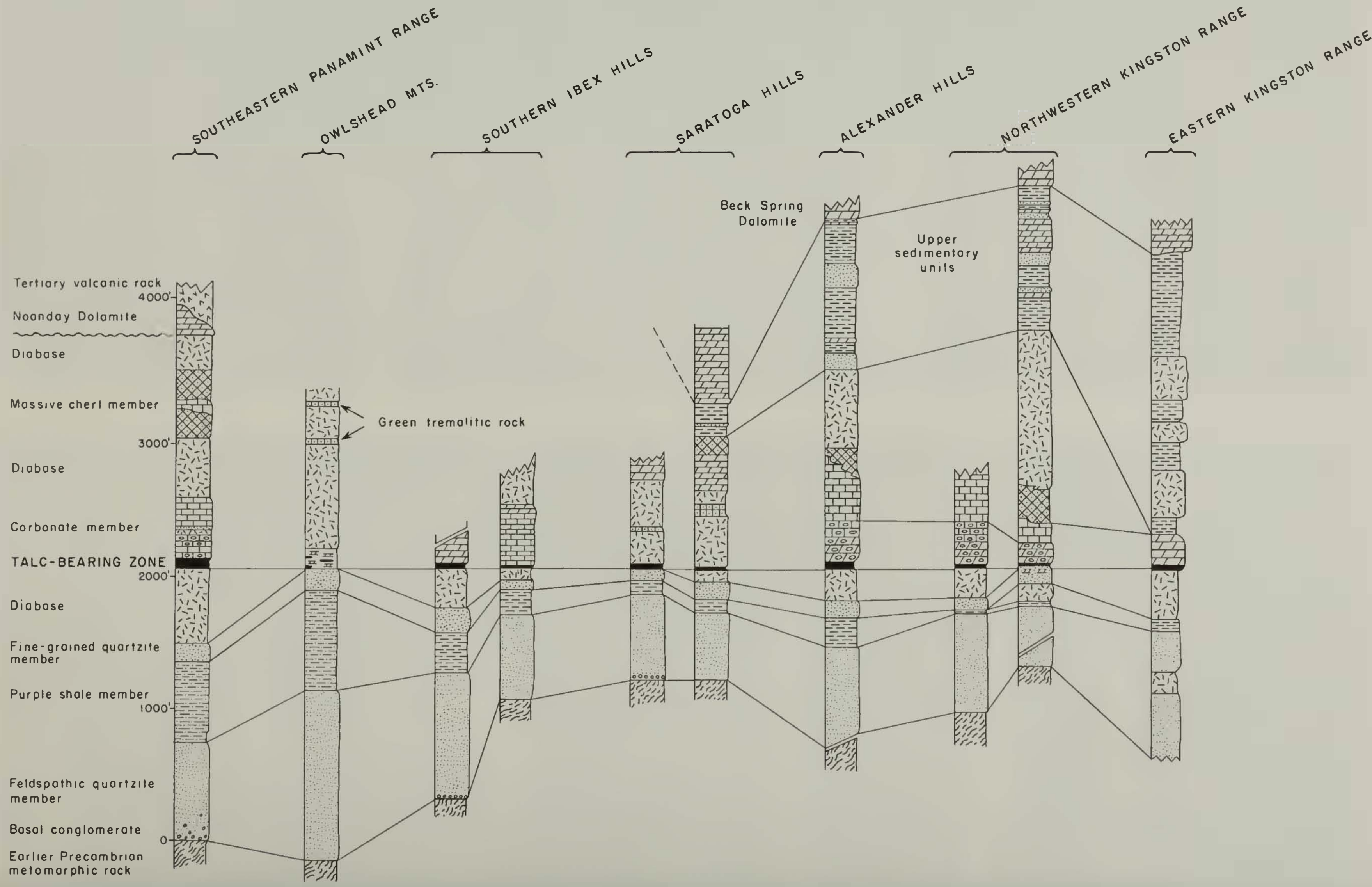

Figure 2. Columnar sections of Crystal Spring Formation, of later Precambrian age, measured at selected localities in talc-bearing belt, and showing stratigraphic position of zones of silication.

dle of the formation have a diverse lithology, and are not divisible into persistent units, they are collectively designated here as the "carbonate member". A "massive chert member" ordinarily overlies the carbonate beds. The sedimentary rocks, of various types, that compose the upper part of the formation, show a persistent heterogeneity, but no persistent members. They will be referred to here merely as the "upper sedimentary units".

FELDSPATHIC QUARTZITE MEMBER

The most persistent of the Crystal Spring members is the feldspathic quartzite which, in the measured sections, ranges in thickness from about 200 feet in the Silurian Hills (Kupfer, 1960) to 1200 or more feet in the Owlshead Mountains. It is ordinarily medium to pale gray, but in the upper part of the member much of the rock is tinted blue or green.

The member has a distinctive, but discontinuous, basal conglomerate with a maximum observed thickness of 25 feet and composed mostly of well-rounded pebbles, cobbles, and boulders as much as 1½ feet in diameter. Much of the conglomerate is composed of fragments of the more resistant rocks of the underlying earlier Precambrian complex; but the most abundant and widespread of the fragments consist of a dense, vitreous quartzite, not noted in the underlying rocks.

The quartzite above the basal conglomerate is characteristically sub-vitreous and feldspathic. The feldspar commonly forms one-quarter to one-third of the rock; potassic grains appear to predominate. In general, the quartzite grades upward from massive, dark-weathering, coarse-grained rock, containing thin layers of pebbly conglomerate, into more thinly bedded, pale-weathering, medium- to fine-grained rock. Some beds high in the member consist of relatively friable sandstone. Water-type cross-laminations are characteristic of the member's entire thickness, and ripple marks, and mud cracks are common in its upper part.

PURPLE SHALE MEMBER

A member characterized by a purple to blue color, and composed of shale (actually argillite) and fine-grained quartzite persistently overlies the basal quartzite member. In measured thickness, it ranges from a minimum of 30 feet in the western Kingston Range to a maximum of about 700 feet in the Owlshead Mountains. In the Owlshead Mountains, Panamint Range, and Silurian Hills, the member is composed mostly of fine-grained quartzite; elsewhere, it is chiefly shale. This member overlies the feldspathic quartzite member with a gradational contact, which, on the accompanying maps (pl. 2B and 2C), was drawn to separate predominantly gray from predominantly purple or blue fine-grained quartzite. Mud cracks and ripple marks are abundant in the shale.

Distinctive pale green to pale blue blotches characterize at least part of the member at all of its observed occurrences. Many of the blotches are spheroidal; others are irregular and are commonly elongate parallel with bedding plans. Thin section observations show that the blotches are centers about which ferric oxide has been reduced to the ferrous form.

FINE-GRAINED QUARTZITE MEMBER

Everywhere except in the Silurian Hills, the observed occurrences of the purple shale member are overlain by a dense, fine-grained quartzite, characteristically green, but locally ranging from gray to pale brown and dark red. This member ordinarily has a thickness of from 50 to 100 feet but is about 200 feet thick in the Superior mine area. Lenticular carbonate layers from a few inches to several feet thick, though subordinate, are common and increase in abundance upward. The carbonate-rich part of the member ordinarily underlies a diabase sill and has been silicated near the contract. These generally are the lowest of the carbonate sediments in the Pahrump Group. Locally, the member also contains subordinate shale and argillite, but is free of the mud cracks, blotches, ripple marks, and cross-bedding found lower in the section.

CARBONATE MEMBER

A brown to pale yellow unit, composed mostly of carbonate strata and ordinarily several hundred feet thick, persistently occurs in the middle of the Crystal Spring Formation and stratigraphically above the quartzitic and shaly units already noted. This unit, here referred to as the "carbonate" member, is generally separated from the underlying, non-carbonate strata by a diabase sill. On the east slope of the Kingston Range, in the Silurian Hills, and on the north slope of the Avawatz Mountains, the member pinches and swells markedly, locally is missing altogether, and in general, thins southward; elsewhere, the member is very continuous.

The composition of the member differs markedly from place to place. In the Kingston Range and Alexander Hills, for example, abundant chert layers (photo 20) occur in its lower half. In the Silurian Hills, the member contains several prominent quartzite beds, each from 15 to 20 feet thick. Yet in the southern part of the Ibex Hills and in the Saratoga Hills the member consists almost wholly of chert- and quartzite-free carbonate material.

The character of the carbonate material in the member likewise is non-uniform. The lower half of the member in the western Kingston Range and Alexander Hills is dark-gray and dolomitic, as well as siliceous, and grades upward into pale brown and pale gray limestone.

In the Saratoga Hills, the entire member is dolomitic. At the southern end of the Ibex Hills the lower part of the member consists mostly of a gray, thin-bedded limestone with subordinate siliceous layers. This rock grades upward into silica-free, equally well-bedded limestone. Superimposed upon this limestone are large, irregular dolomite masses, the outlines of which lie athwart the sedimentary layering. Bedding planes, though detectable in these dolomite masses, are much less distinct than in the limestone. The concentration of MgO, thus indicated, probably occurred at a time distinctly later than the sedimentation. But at other localities the dolomite bodies are stratiform.

In the Sheep Creek area of the Avawatz Mountains (pl. 1D) the carbonate member is represented by dolomite strata, now partly silicated, which alternate with shaly and quartzitic strata, all totaling no more than 300 feet in thickness.

MASSIVE CHERT MEMBER

A layer of dark massive chert, generally 100 to 500 feet thick, lies above the carbonate member at nearly every locality where the middle part of the Crystal Spring Formation was observed. It was found absent only in the Silurian Hills and in the eastern part of the Kingston Range. At most places, the massive chert member is overlain, and separated from the upper sedimentary units, by a diabase sill. The sill commonly encloses smaller bodies of chert. In the Saratoga Hills, the chert layer is thick and persistent and is unassociated with diabase. In some places, especially in the Alexander Hills, the chert layer thickens and thins markedly and shows an irregular contact with the underlying dolomite.

The chert ordinarily is varicolored from shades of brown through dark red to black and thereby jasperoid in appearance. Although massive in most localities, it commonly shows thin banding which is marked by color differences. In the Saddle Peak Hills and southernmost Saratoga Hills, it contains layers of angular fragments (B. W. Troxel, personal communication) and apparently is of sedimentary origin.

UPPER SEDIMENTARY UNITS

The shale, quartzite, and dolomite, which compose the upper sedimentary units of the Crystal Spring Formation, attain total thicknesses of 200 to 1200 feet in the measured sections. They are well exposed in the Saratoga Hills, Saddle Peak Hills, Alexander Hills, and the Kingston Range. The strata are variously colored, mostly in shades of gray and brown, and form even layers of contrasting lithology to give the landscape a prominent banded appearance.

Diabase

DISTRIBUTION

All but a small part of the diabase in the Pahrump Group is confined to sill-like bodies, a few tens of feet to 1500 or more feet thick which lie immediately below, within, or immediately above the carbonate member of the Crystal Spring Formation. In some places, notably in the central part of the Kingston Range and on the north slope of the Owlshead Mountains, the diabase is so abundant that the carbonate member appears as a septum. A diabase sill occurs within the feldspathic quartzite member on the east side of the Kingston Range and several small sills occur in the lower part of the Crystal Spring Formation at Sheep Creek in the Avawatz Mountains. Diabase bodies also are abundant in the earlier Precambrian complex, and numerous small feeder dikes cut the lower parts of the Crystal Spring Formation.

The diabase has been most persistently emplaced at or near the base of the carbonate member. Nearly everywhere it forms a multiple sill that is as widespread as the formation is exposed. At only four places were the carbonate and underlying members observed to be unbroken by diabase. These are as follows: the lower part of Warm Spring Canyon (pl. 2B) in the Panamint Range; the vicinity of the Montgomery mine in the Panamint Range; the west face of the part of the Ibex Hills that lies southwest of Ibex Spring; and the vicinity of the Omega mine in the northwestern part of the Kingston Range (pl. 1A). As these discontinuities in the occurrence of diabase are local features, all of the diabase at this stratigraphic position is presumed to be part of a single sill that originally was at least as extensive as the belt (75 miles long and 15 miles wide), that contains the Crystal Spring Formation.

This diabase body is here referred to as the "Ibex sill" for its excellent exposures along the east face of the Ibex Hills north of Ibex Spring (photo. 3). The sill ranges in observed thickness from about 50 feet at one place in the Western mine area to more than 1500 feet in the Owlshead Mountains. Ordinarily, the sill is 150 to 500 feet thick. That it is an intrusive, rather than an extrusive body, is shown by the contact metamorphic effects in the overlying rocks and by continuous, fine-grained selvages, several feet thick, along its upper as well as its lower margins.

In most of its thicker occurrences, the sill is a multiple body. This is shown by very elongate septa or screens of sedimentary and metasedimentary rocks, within the sill, some of which are aligned upon what appears to be a stratigraphic horizon. These septa occur at various levels, and are themselves bordered, top and bottom, by fine-grained diabase selvages. Internal selvages, other from these bordering the septa also were noted.

Diabase bodies higher in the formation are commonly as thick as or thicker than the Ibex sill, but are not as persistent. The largest are those that directly overlie the carbonate member. In the type section at Crystal Spring in the Kingston Range, a body of diabase, as much as 1500 feet thick, separates this member from the upper sedimentary units. Other diabase bodies, from 500 to 1000 or more feet in maximum thickness, are present in the upper part of the formation in most if its other occurrences. In the Saratoga Hills, and probably in the Silurian Hills, these higher bodies of diabase are missing. Diabase sills, from a foot to several tens of feet thick, are common within the carbonate member. Like the Ibex sill, those within and above the carbonate member have top, bottom, and internal selvages. Septa of sedimentary and metasedimentary rock also are abundant in the sills above the member.

PETROLOGY AND PETROGRAPHY

Examination of 15 thin sections of the diabase indicates that it originally was composed of from 30 to 60 percent plagioclase (mostly calcic labradorite), from 30 to 60 percent mafic minerals (principally hypersthene and augite) and from 2 to 10 percent magnetite and ilmenite. Considerably more than half of the volume of the specimens examined in thin section consists of the secondary minerals uralite, chlorite, sericite and clinozoisite (?). The widespread and pervasive character of the alteration suggests a deuteric origin rather than a hydrothermal effect genetically unrelated to the diabase.

Preliminary megascopic and microscopic examinations of the diabase strongly suggest that a mineralogic homogeneity, within the above-noted limits, persists both vertically and laterally within the diabase bodies. In a few places unusually high concentrations of feldspar were noted but such concentrations seem to be erratic in distribution and not attributable to a gravitational differentiation.

The diabase is uniformly dark-green to greenish-black. It is mostly medium-grained, but coarse-grained facies are common in the central parts of some of the larger bodies; the selvages are typically fine grained. The texture is generally diabasic, but a porphyritic texture showing phenocrysts of plagioclase and hypersthene, was noted locally in the selvages. The coarser diabase locally contains abundant, irregularly shaped phenocrysts of plagioclase which form the above-noted high feldspar concentrations. In thin section, rock from the upper margin of the lower sill in Warm Spring Canyon was observed to be very rich in biotite, a feature that may be characteristic regionwide.

The plagioclase (mostly calcic labradorite) of the ordinary Crystal Spring diabase is in laths that range generally from one-half mm. to two mm. in length. It has altered principally to sericite and clinozoisite (?), but irregular inclusions of chlorite are common. The plagioclase phenocrysts of the porphyritic rock appear to be sodic labradorite.

Augite, mostly in grains less than 1 mm. in diameter, forms 5 percent or less of the volume of the rock in the thin sections examined, and appears to be a remnant of the primary mafic fraction. Uralite, by far the most abundant dark constituent, is partly, perhaps wholly, an alteration of augite. Most of the uralite, however, is unassociated with remnants of earlier mafic minerals. It occurs in irregular grains, from 2.5 mm. to 10 mm. in diameter, and also forms felty aggregates. The uralite shows all degrees of chloritization, an alteration particularly well-displayed along cleavage fractures in the larger uralite grains.

The hypersthene, rarely present in proportions greater than one or two percent, is mostly in subhedral grains less than 0.5 mm. in maximum dimension. Unlike the other primary constituents of the diabase, the hypersthene is little altered.

The opaque grains, irregular in outline, are as much as 3 mm. long. Magnetite is the most abundant, but ilmenite is commonly intergrown with it.

Biotite shreds, thinly scattered through most of the thin sections, and very abundant in the previously mentioned selvage in Warm Spring Canyon, may be remnants of primary grains. The biotite is partly chloritized. Quartz is uncommon but exists locally as small interstitial anhedral grains. Apatite is an abundant accessory; sphene is less common.

CHEMICAL COMPOSITION

Although a systematic study of the chemistry of the diabase bodies lies beyond the scope of this report, the similarity of chemical analyses of four specimens taken from the centers of sills that border the carbonate member (columns 1–4, table 1), suggests that the bulk of the material in the sills is of rather uniform composition. A comparison of the average of these four analyses with a single analysis of diabase from a dike that cuts earlier Precambrian gneiss beneath the Crystal Spring Formation (columns 5 and 6, table 1) suggests that the higher bodies are distinctly richer in water, but that otherwise the bodies within the formation and those below it are of similar composition. An analysis of a specimen from the biotite-rich facies along the upper 2 to 4 feet of the sill that underlies the principal talc deposit in Warm Spring Canyon (column 7) differs from the analysis of a specimen taken 15 feet lower (column 3), mainly in that the biotite-rich rock has a markedly lower SiO_2 and CaO content and correspondingly higher MgO and K_2O content than the typical diabase in the central part of the sill; this suggests contamination of the diabase body along its contact with dolomitic strata and the transfer of SiO_2 to the silicated zones and of MgO from the strata to the diabase.

The available analyses of the diabase bodies of the Death Valley region, when compared with analyses from some of the better known diabase bodies elsewhere in the world (column 8; see also Daly, 1933, p. 406), are distinctly poorer in SiO_2 and CaO and richer in H_2O (+105°C). The relatively low SiO_2 content (45.2 percent average for samples 1-4 vs. 51.9 percent average for other diabases as shown in column 8) may reflect a general impoverishment in SiO_2 of the diabase and, therefore, suggests an even more abundant source of SiO_2 for the silication than would be provided by the border zones of the diabase bodies. Pointing against such an impoverishment, however, is the uniformity in the SiO_2 content of all four specimens from the central parts of diabase bodies, both high and low in the Crystal Spring Formation and in the underlying metamorphic rocks, whereas the introduction of silica appears to have been most abundant and widespread along the sill at the base of the carbonate member. The analytical data provides no suggestion that the diabase has been impoverished in MgO as (1) the MgO content of the four above-noted specimens is quite uniform and typical of diabases elsewhere, and (2) the specimen of biotite-rich rock at the border of the lower sill has an unusually high MgO content.

The five analyses from diabase bodies within the Crystal Spring Formation show an average H_2O (+105°C.) content of 3.2 percent, as compared with 1.01 percent for the specimen from the dike that cuts earlier Precambrian gneiss beneath the formation. Should this be a persistent distinction between the diabase bodies in the two settings, the most ready source of additional water for the diabase in the Crystal Spring Formation would have been ground water which, when the diabase was intruded, probably was much more abundant in the then recently deposited and weakly consolidated strata than in the underlying metamorphic rocks.

Table 1. Chemical analyses of diabase samples from Death Valley area compared with average composition of diabases elsewhere in the world. Analyses 1–4, 6, 7 by W. H. Herdsman, Glasgow.

	1.	2.	3.	4.	5.	6.	7.	8.
SiO_2	45.96	45.54	45.71	43.79	45.2	45.06	35.76	51.9
Al_2O_3	16.86	15.31	15.41	16.92	16.1	16.79	12.75	15.1
FeO	7.47	11.07	11.19	10.78	10.1	10.49	10.06	9.0
Fe_2O_3	3.18	2.41	3.34	3.80	3.2	3.89	3.94	1.3
TiO_2	1.56	3.67	3.81	2.87	3.0	3.21	3.61	1.3
CaO	6.02	6.76	6.89	6.23	6.5	8.01	4.29	10.0
MgO	6.47	5.12	4.68	6.04	5.6	5.65	14.68	6.6
K_2O	2.72	1.09	.66	1.47	1.5	1.88	9.14	.9
Na_2O	3.35	4.09	4.48	3.26	3.8	3.02	.54	2.1
H_2O −105°C	.06	.14	.07	.23	.1	.02	.08	.5
H_2O +105°C	3.18	3.54	2.43	3.62	3.2	1.01	3.44	.9
CO_2	2.63	.22	.27	Nil	.8	.20	.80	
P_2O_5	.32	.71	.71	.38	.5	.41	.63	.2
SO_3	.02	.03	.08	Nil		.03	.01	
MnO	*	*	*	.35		*	*	.2
	99.80	99.70	99.73	99.74	99.6	99.67	99.73	100.0

* Not determined
1. Center of sill above carbonate member in lower part of Warm Spring Canyon, Panamint Range (pl. 2B).
2. Center of sill beneath carbonate member at Big Talc workings, Grantham mine, Panamint Range (pl. 2B).
3. About 15 feet beneath upper margin of sill at White Point workings, Grantham mine, Panamint Range (pl. 2B).
4. Center of sill beneath carbonate member near No. 3 shaft, Western mine, Alexander Hills.
5. Average of columns 1–4.
6. Center of dike that cuts earlier Precambrian gneiss, about half a mile east of Noonday mine camp, Nopah Range.
7. Upper margin of sill beneath carbonate member at White Point workings, Grantham mine, Panamint Range.
8. Average diabase, sills of Tasmania; Palisade sill, New Jersey; Whin sill, England; and Karroo diabase, South Africa (Turner, F. J., and Jean Verhoogen, 1951, p. 187).

AGE AND ENVIRONMENT OF EMPLACEMENT

A later Precambrian age is indicated for the diabase bodies by (1) their presence in rocks no younger than the Crystal Spring Formation and (2) the presence of the aforementioned fragments of diabase in the Kingston Peak Formation. Depending upon the stratigraphic position of the sills and whether or not their intrusion preceded the deposition of the Beck Spring Dolomite, they appear to have formed under sedimentary loads now represented by rock thicknesses of 200 to 2500 feet. Regardless of the actual load and the relative age of the diabase with respect to the Beck Spring Dolomite, the diabase bodies were intruded into strata that probably were still poorly consolidated as well as saturated with marine water.

METAMORPHISM

Regional Metamorphism

As previously recognized by both Noble (1934) and Hewett (1956), the rocks of the Pahrump Group show a regional metamorphism of mild intensity and comparable with that of the Paleozoic sedimentary rocks which overlie them. The carbonate rocks, although crystalline, are mostly fine grained and generally show little or no reaction with the chert layers they contain. The most arenaceous of the Crystal Spring sediments have become quartzites, but the quartz and feldspar grains commonly retain their original outlines. The shaly layers, which ordinarily have been transformed to argillites, only locally show a secondary schistosity. Indeed, most of the planar structures throughout the Pahrump section are sedimentary features.

Contact Metamorphic Bodies (Silicated Zones)

In contrast with the relatively mild effects of regional metamorphism, are the pronounced and widespread zones of silicate minerals which have formed by the contact metamorphism of the carbonate member. The zones range in thickness from a few inches to 200 feet or more and are in contact with or close to the diabase sills. The strata at or near the base of the carbonate member, which are proximate to the lowest of the large sills, are the most persistently altered and show some degree of silication wherever the sill is observed. Moreover, virtually all of the bodies of commercial talc that are sufficiently large to be mined occur in the silicated zones at this stratigraphic position. At many places these bodies of silicated rock, composed chiefly of talc and tremolite, can be traced laterally for several thousands of feet. In a general sense, therefore, all of the observed occurrences of silicated rock that represent alterations of the lower carbonate strata are segments of the same exceedingly extensive, but locally discontinuous zone. When formed, this zone underlay an area at least as large as the present talc-bearing region, but it has since been so severely disrupted by faulting and so extensively eroded, that its localities of exposure are now widely separated. In the descriptions to follow the term "zone" will be applied to any body of silicated rock that, at a given locality, occupies a persistent stratigraphic position. The phrase "body of commercial talc" will be applied to any essentially intact part of a given zone that consists of marketable magnesium silicate rock.

Silicated zones also border the sills higher in the member and compose most of the septa in these and in the Ibex sill as well. The septa are characteristically

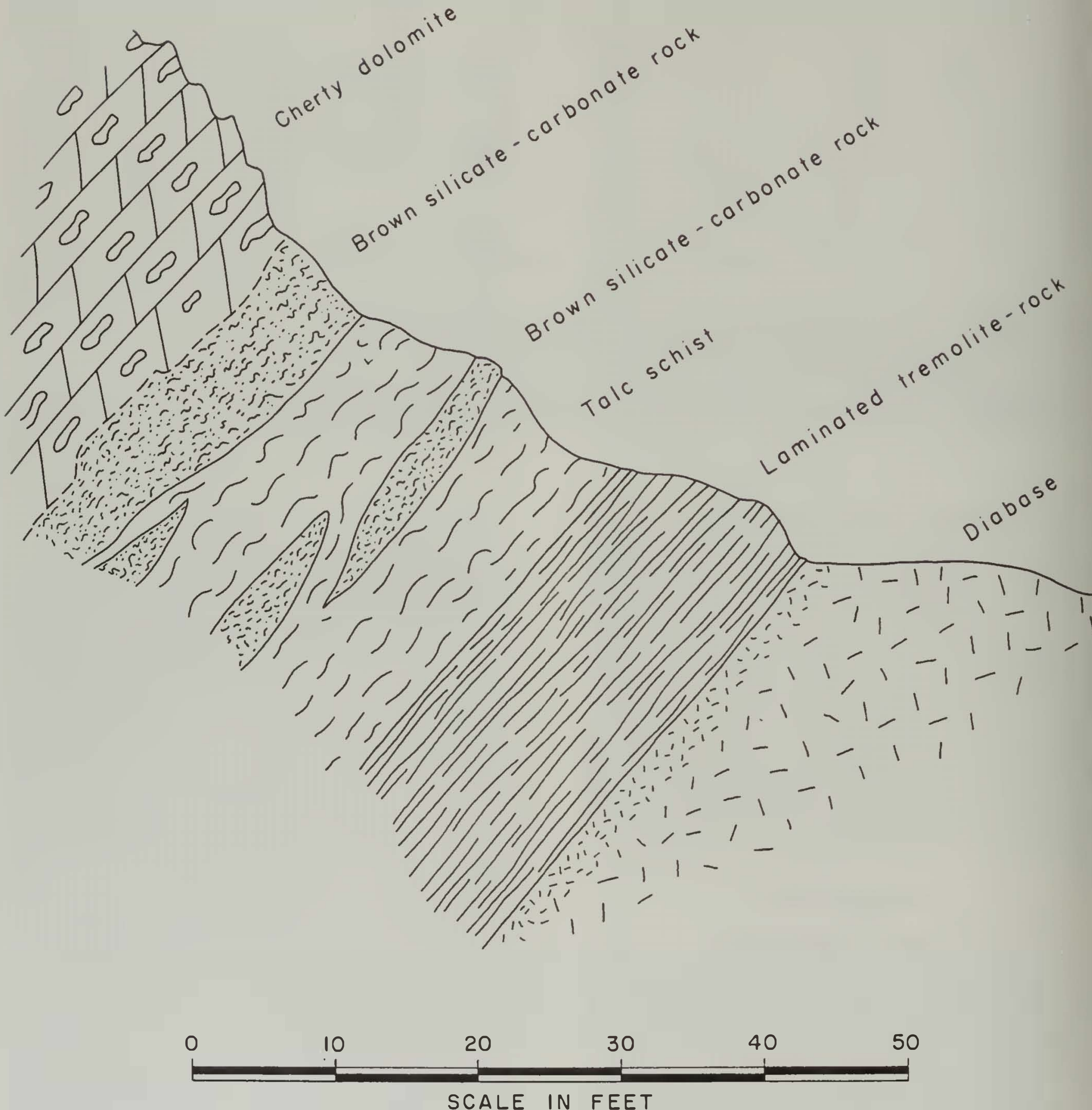

Figure 3. Diagrammatic cross section through typical zone of silication such as that at Western mine.

several tens of feet wide and several hundred to several thousand feet long. Many of the higher contacts of diabase and carbonate rock, however, show little or no silication.

GENERAL FEATURES OF THE SILICATED ROCKS

All of the silicated rocks are characteristically fine grained and all are rich in magnesium silicate minerals. But these rocks consist of several varieties distinguishable by either mineralogic or textural differences or by both. The general name "white magnesium silicate rock", or simply "white rock" is here applied to a variety composed mostly of magnesium silicate minerals and notably poor in alumina-, alkali-, and iron-bearing minerals. It is white to very pale shades of gray, green, or pink. It consists principally of talc, tremolite, chlorite, and carbonate material which occur in various proportions and combinations. The rock also contains traces of feldspar and quartz, and less

Table 2. Chemical anaylses of commercial talcs from southern Death Valley-Kingston Range region. These, considered collectively, are representative of talcs mined in the region, but the individual samples analyzed are not necessarily representative of the deposit where collected. Analyses supplied by the companies shown in parentheses.

<table>
<tr><th></th><th>SiO_2</th><th>MgO</th><th>Al_2O_3</th><th>CaO</th><th>FeO
Fe_2O_3</th><th>K_2O</th><th>Na_2O</th><th>H_2O
−105°C.</th><th>H_2O
+105°C.</th><th>CO_2</th></tr>
<tr><td>1.</td><td>49.71</td><td>28.71</td><td>1.84</td><td>9.20</td><td>0.16</td><td>0.61</td><td>1.80</td><td colspan="3">7.90</td></tr>
<tr><td>2.</td><td>53.00</td><td>24.41</td><td>3.15</td><td>7.37</td><td>0.91</td><td>0.22</td><td>0.30</td><td>0.43</td><td>4.48</td><td>5.61</td></tr>
<tr><td>3.</td><td>51.32</td><td>29.51</td><td>1.36</td><td>5.27</td><td>0.42</td><td colspan="2">1.68</td><td>0.51</td><td colspan="2">9.98</td></tr>
<tr><td>4.</td><td>43.17</td><td>26.59</td><td>0.69</td><td>9.33</td><td>0.73</td><td colspan="2">1.79</td><td>0.59</td><td colspan="2">17.11</td></tr>
<tr><td>5.</td><td>54.31</td><td>26.58</td><td>1.08</td><td>5.47</td><td>0.32</td><td colspan="2">0.54</td><td>0.34</td><td colspan="2">11.36</td></tr>
<tr><td>6.</td><td>49.11</td><td>26.61</td><td>1.16</td><td>9.66</td><td>0.32</td><td colspan="2">0.59</td><td>0.11</td><td colspan="2">12.49</td></tr>
<tr><td>7.</td><td>54.37</td><td>27.10</td><td>2.73</td><td>5.36</td><td>0.23</td><td colspan="2">*</td><td>0.03</td><td colspan="2">11.93</td></tr>
<tr><td>8.</td><td>55.8</td><td>26.85</td><td>2.23</td><td>5.45</td><td>0.09</td><td colspan="2">*</td><td colspan="3">8.2</td></tr>
<tr><td>9.</td><td>52.50</td><td>28.10</td><td>2.43</td><td>8.8</td><td>0.17</td><td colspan="2">*</td><td colspan="3">8.2</td></tr>
<tr><td>10.</td><td>55.70</td><td>30.73</td><td>1.49</td><td>7.16</td><td>0.33</td><td>1.6</td><td>1.7</td><td colspan="3">3.54</td></tr>
<tr><td>11.</td><td>57.35</td><td>27.95</td><td>.75</td><td>5.7</td><td>0.35</td><td>0.58</td><td>1.81</td><td>0.57</td><td>3.22</td><td>3.05</td></tr>
<tr><td>12.</td><td>56.62</td><td>27.75</td><td>1.14</td><td>5.91</td><td>0.18</td><td>0.44</td><td>1.13</td><td>0.10</td><td>3.94</td><td>4.40</td></tr>
<tr><td>13.</td><td>54.77</td><td>26.05</td><td>1.08</td><td>5.81</td><td>0.38</td><td>0.21</td><td>0.27</td><td>0.23</td><td>4.58</td><td>4.56</td></tr>
<tr><td>14.</td><td>51.25</td><td>31.68</td><td>1.38</td><td>5.07</td><td>0.94</td><td colspan="2">*</td><td colspan="3">9.43</td></tr>
<tr><td>15.</td><td>54.80</td><td>26.82</td><td>1.15</td><td>6.24</td><td>0.18</td><td>0.18</td><td>0.72</td><td>0.42</td><td>3.63</td><td>4.75</td></tr>
<tr><td>16.</td><td>56.42</td><td>28.11</td><td>0.58</td><td>5.63</td><td>0.28</td><td>0.02</td><td>0.12</td><td>0.09</td><td>4.12</td><td>4.46</td></tr>
<tr><td>17.</td><td>46.38</td><td>23.80</td><td>1.87</td><td>10.76</td><td>0.34</td><td>0.97</td><td>1.28</td><td>0.18</td><td>2.22</td><td>8.17</td></tr>
<tr><td>18.</td><td>51.30</td><td>29.52</td><td>1.08</td><td>6.20</td><td>0.88</td><td>0.05</td><td>0.16</td><td colspan="3">10.65</td></tr>
<tr><td>19.</td><td>56.88</td><td>31.29</td><td>0.45</td><td>4.92</td><td>0.63</td><td>*</td><td>*</td><td colspan="3">5.33</td></tr>
<tr><td>20.</td><td>55.90</td><td>28.77</td><td>1.24</td><td>4.77</td><td>0.31</td><td>0.28</td><td>0.44</td><td>0.10</td><td>4.40</td><td>4.36</td></tr>
<tr><td>21.</td><td>51.09</td><td>25.36</td><td>0.69</td><td>9.32</td><td>0.39</td><td>1.70</td><td>2.81</td><td>0.11</td><td>2.84</td><td>5.21</td></tr>
<tr><td>22.</td><td>54.51</td><td>26.27</td><td>0.44</td><td>7.24</td><td>0.32</td><td>2.79</td><td>1.99</td><td>0.09</td><td>3.87</td><td>3.30</td></tr>
<tr><td>23.</td><td>53.95</td><td>28.54</td><td>0.66</td><td>4.81</td><td>0.33</td><td>1.37</td><td>0.92</td><td>0.06</td><td>3.77</td><td>4.97</td></tr>
<tr><td>24.</td><td>54.30</td><td>25.56</td><td>1.74</td><td>7.04</td><td>0.46</td><td>0.75</td><td>0.49</td><td>0.19</td><td colspan="2">8.37</td></tr>
</table>

* Not determined.
1. Laminated tremolite rock from Acme mine (Southern California Minerals Co.).
2. Massive talc rock from Booth mine (Sierra Talc Co.)

3–6. Various samples from Atlas mine (Western Talc Co.).

7. Talc schist from Crystal Spring mine (Sierra Talc Co.).
8. Massive talc rock from Death Valley mine (Kennedy Minerals Co.).
9. Laminated talc rock from Eclipse mine (Kennedy Minerals Co.).
10. Talc schist from Excelsior mine (Southern California Minerals Co.).

11–12. Massive talc rock from Grantham mine (Sierra Talc Co.).

13. Talc schist from Ibex mine (Sierra Talc Co.).
14. Talc schist from Markley mine (Sierra Talc Co.).
15. Talc schist from Monarch mine (Sierra Talc Co.).
16. Massive talc rock from Montgomery mine (Sierra Talc Co.).
17. Talc schist from Pleasanton mine (Sierra Talc Co.).
18. Massive talc rock from Pongo mine (Southern California Minerals Co.).
19. Massive talc rock from Smith mine (Sierra Talc Co.).
20. Talc schist from Superior mine (Southern California Minerals Co.).
21. Laminated tremolite rock from Western mine (Western Talc Co.).
22. Massive talc-tremolite rock from Western mine (Western Talc Co.).
23. Talc schist from Western mine (Western Talc Co.).
24. Blend from Western mine (Western Talc Co.).

than one-half of one percent, by weight, of iron oxide. From deposit to deposit and from place to place within a given deposit, the mineral grains are oriented differently so that some of the rock is blocky, some is thinly and evenly laminated, and some is schistose in the sense that the mineral grains are dimensionally aligned parallel with the foliation. All of the commercial material can be classed as white magnesium silicate rock, but much of the white rock is made subcommercial by a high content of carbonate material.

Other silicated rocks are distinctly darker than the white rock and are of no present commercial value. They ordinarily contain from 10 to 60 percent alkali feldspar (both albite and orthoclase) and from 5 to 25 percent quartz. The most abundant of these rocks is a massive to platy, pale green to pale bluish gray tremolitic variety, here designated as "green tremolitic rock". Its other common constituents are calcite, diopside, chlorite, and opaque material.

A less abundant, but very widespread sub-commercial rock is a crudely foliated, pale yellowish orange to reddish brown variety, here named "brown silicate-carbonate rock". It generally occurs along the borders and in the outer parts of bodies that consist largely of the white rock. It forms the hanging-wall rock of most of the bodies of commercial talc that overlie diabase. This rock, like the green tremolitic rock, ordinarily contains appreciable fractions of albite, orthoclase, carbonate, and quartz. In general, it is distinguished from the green rock by a much lower tremolite content, an abundance of sericite(?) the presence of other hydrous, magnesium-rich minerals such as talc, chlorite, serpentine or phlogopite, and a pervasive limonitic stain.

in the silicated zones that are associated with the Ibex sill and altered from the basal beds of the carbonate member. Some of these lower zones consist almost entirely of the white rock, but most also contain layers and lenses of the more feldspathic alteration rocks. The brown rock most commonly occurs as layers that separate bodies of talc-tremolite rock and unaltered strata of the carbonate member. It also interfingers with and forms septa in the outer parts of these bodies. Less common in the lower zones, but by no means rare, are lenses and layers of green tremolitic rock.

The silicated zones that border the diabase bodies higher in the carbonate member, and also comprise septa in these as well as in the lower sill, consist predominantly of green tremolite rock. Zones consisting largely or wholly of the white alteration rock locally border the higher diabase bodies, but such zones are discontinuous and rarely exceed four feet in width.

Bodies of Commercial Talc

STRATIGRAPHIC POSITION AND RELATIONSHIP TO THE DIABASE BODIES

Most of the white magnesium silicate rock that occurs within 50 feet of the margins of the Ibex sill represents such a complete reconstitution of the lower strata of the carbonate member that it constitutes talc of commercial interest. The thickest and most persistent of these commercial talc-bearing zones occur in areas where the intrusion of the diabase has separated the carbonate member from the underlying quartzite and shale. Consequently, most of the commercial talc bodies lie directly above the sill. The principal bodies of the Grantham, Death Valley, Eclipse, Monarch, Sheep Creek, Western, and Acme deposits for example, occupy this position. Locally, where the sill was intruded above the lower carbonate strata, bodies of commercial talc lie below the sill, as do those at the Superior, White Cap and Vulcan deposits. At these deposits the carbonate strata above the sill are less strongly silicated and have not been mined.

In other places the sill lies a few feet to a few tens of feet below the base of the carbonate member. At several localities, therefore, a body of commercial talc

Table 3. Chemical analyses of subcommercial silicated rocks associated with diabase bodies of the Crystal Spring Formation. Analyst: Alberta J. MacArthur, Sierra Talc Co.

	SiO_2	MgO	Al_2O_3	CaO	FeO Fe_2O_3	K_2O	Na_2O	H_2O −105°C.	H_2O +105°C.	CO_2
1.	35.12	12.24	9.22	13.95	1.11	4.27	1.86	0.14	0.95	21.00
2.	60.90	9.88	8.85	5.23	1.91	4.66	1.46	0.16	2.12	5.30
3.	57.75	6.02	11.54	7.48	2.22	7.67	2.30	0.17	3.18	2.98
4.	62.85	6.12	14.60	1.32	1.43	10.37	2.16	0.17	1.17	0.22

1. Brown silicate-carbonate rock from Western mine area.
2. Brown silicate-carbonate rock from Smith mine area.
3. Green tremolitic rock from Grantham mine area.
4. Green tremolitic rock from Grantham mine area.

Well-defined planar features, paralleling the margins of the sills and the sedimentary bedding, characterize each of the three rock types both in gross and in textural detail. Such parallelism is shown by the layers and elongate lenses of the various alteration rocks that compose individual zones, and by the schistose or laminated textures of most of these rocks. Some of the bodies, however, have a schistosity that is locally discordant with their margins.

DISTRIBUTION OF ROCK TYPES

Most of the white magnesium silicate rock and virtually all of the brown silicate-carbonate rock occur

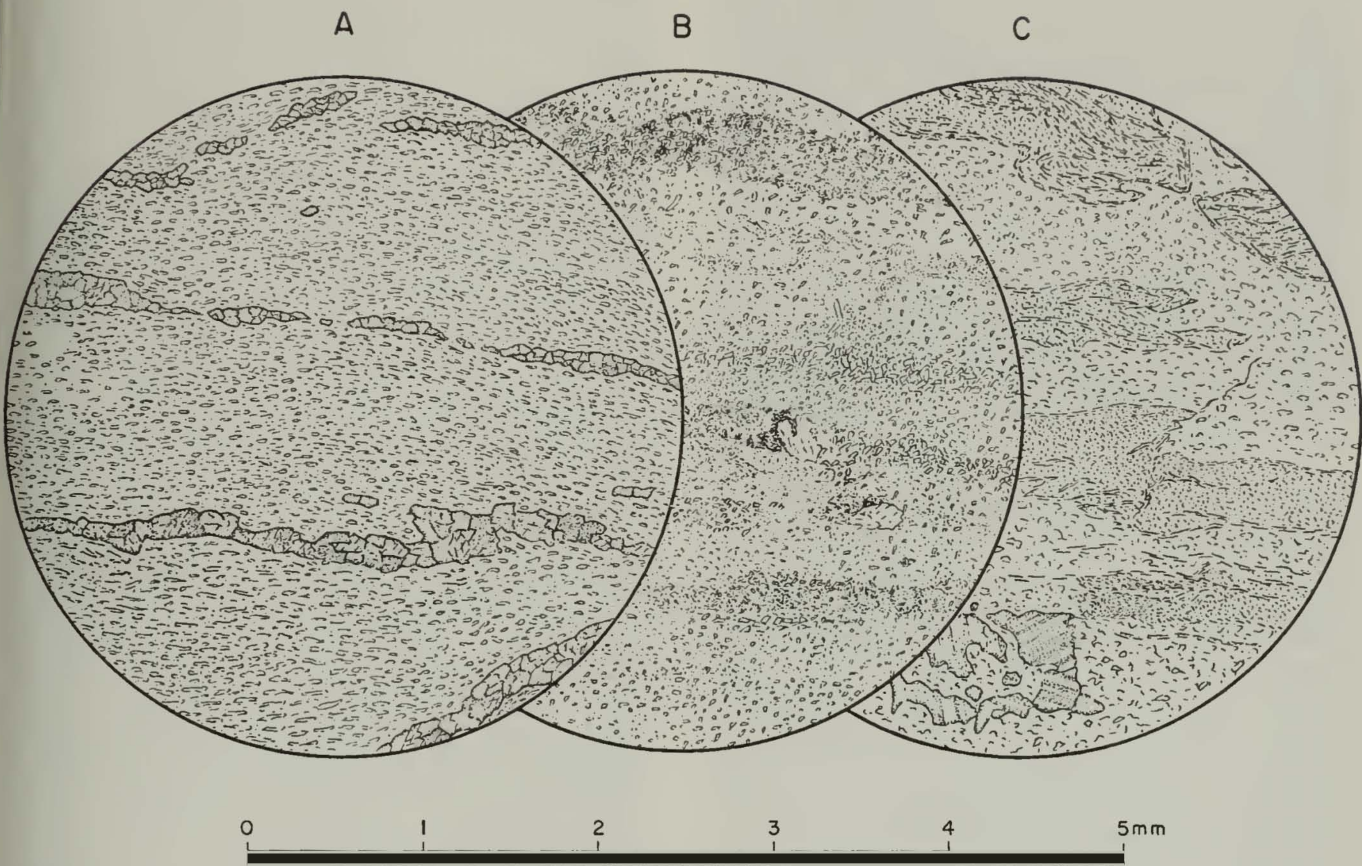

Figure 4. Microsketches of representative commercial talcs from southern Death Valley-Kingston Range region. A. Talc schist from Excelsior mine showing veinlets and grains of carbonate material in a matrix of minute grains of talc and subordinate chlorite. B. Laminated tremolite rock from Western mine. Tremolite is only major constituent. C. Massive talc rock from Grantham mine, showing talcose matrix (light shading) which contains plumose aggregates of chloritic material (darker shading) and carbonate grains (lower part) deeply corroded by talc.

is separated from the sill by a layer of quartzite or argillite. Examples are the Smith, Crystal Spring, and Omega deposits. At still other localities, bodies of commercial talc occur in septa enclosed by diabase, but represent alterations of strata that once existed low in the carbonate member. Such bodies exist at the Saratoga, Caliente, and Bonnie mines.

In some of the thickest zones of silicated rock, commercial talc has been mined from bodies that lie within walls of subcommercial material and 20 or 30 feet from the margin of the diabase sill. A second body, higher than the main body, has been mined at both the Grantham and Death Valley mines. At the Rainbow mine, the body of mineable talc is separated from the upper margin of the lower sill by a layer of green tremolitic rock several tens of feet thick.

The talc body at the Jim Francis mine is unusual in that it consists of a lens that extends at a high angle from the diabase sill into the carbonate member. One of the talc bodies at the Montgomery mine also is atypical, as it borders a diabase dike, and occurs at one of the few places where the beds in and below the lower part of the carbonate member form a continuous sequence unbroken by a diabase sill. This deposit extends outward from the dike and parallel with the bedding in the Crystal Spring strata and is an alteration of the lower carbonate strata.

As the talc-bearing rock is inherently weaker than carbonate rock, diabase, or quartzite, surfaces of movement are common within the talc bodies. In some places this movement has been so severe that much or all of the part of the Crystal Spring Formation that lies below the carbonate member has been faulted out by movement of carbonate blocks on talc-lubricated surfaces. The bodies of commercial talc that lie along such surfaces are irregular and discontinuous, as, for example, are the Booth and Donna Loy deposits. Both of these deposits are overlain by cherty dolomite and underlain by earlier Precambrian gneiss, although, nearby, the dolomite-gneiss interval is occupied by a 1500-foot thickness of diabase and Crystal Spring strata.

As the zones that contain bodies of commercial talc are variously disposed with respect to the diabase sill, the wall rocks differ from locality to locality. Most of the zones have footwalls of diabase and hanging-walls of carbonate strata, whereas numerous others have quartzite footwalls and carbonate rock hanging-walls. Much less abundant are those for which diabase forms both walls; the ones for which diabase forms hanging-walls, and quartzite the footwalls; and the zones for which carbonate strata form the hanging-walls and older Precambrian metamorphic rocks the footwalls. As most of the zones of silicated rock contain much rock of sub-commercial grade, such material commonly forms one or both of the walls of individual bodies of commercial talc.

DIMENSIONS OF THE BODIES

Wherever observed, the zones of silicated rock that lie along the upper margin of the Ibex sill can be traced laterally on the surface to points where they are faulted off or extend beneath younger rocks. The zones that underlie the sill or are separated from the upper margin of the sill by layers of quartzite are less continuous. The bodies of commercial talc in some of the localities persist for the full lengths of the exposures of the zones; in the others they are discontinuous because they grade laterally into non-commercial silicated rock or have been caused to pinch out by fault movements within the zones.

Most of the commercial talc occurs in bodies several hundred to several thousand feet long and five to 80 feet wide. The average width of the bodies that have been mined lies within the range of 10 to 20 feet.

The largest of the continuously exposed bodies of commercial talc—the principal body in the Western mine area—is at least 5000 feet long and 80 feet in maximum width. The talc-bearing zone at the Warm Spring mine, although poorly exposed and broken into several segments by cross faults, is probably of comparable length. Bodies of commercial talc from 1000 to 2000 feet in exposed length have been proved at the Death Valley, Superior, and Monarch mines.

Several of the smaller bodies have bottomed within 200 feet of the surface and apparently have been largely worked out. The down-dip limits of most of the bodies, however, remain undetermined. The deepest penetration is that of a 560-foot inclined shaft at the Superior mine.

INTERNAL STRUCTURE OF THE TALC-BEARING ZONES

Although the zones that contain large bodies of white commercial talc show broad similarities, the rocks that compose the bodies show marked differences in mineralogy and texture. Some of the bodies consist of essentially one rock type from wall to wall, but most consist of two or three layers of alteration rock.

Some of the white magnesium silicate rock shows a decussate to granular texture that causes the rock to break into massive blocks; some is composed of minute lamellae of contrasting grain size; and some contains dimensionally aligned grains, to form friable schist.

The mineral content of the white rocks differs principally in relative abundance of talc and tremolite. One generally is present to the virtual exclusion of the other; rarely do the two exist in comparable proportions. In the massive and thinly laminated rocks, either talc or tremolite predominates, but in the schistose rocks, talc is invariably the more abundant. These differences permit a subdivision of the commercial talc into the following five varieties: (1) laminated talc rock, (2) laminated tremolite rock, (3) massive tremolite rock, (4) massive talc rock, and (5) foliated talc rock. The typical individual layer within a given body contains only one of these varieties, but, in a few places, lateral gradations from one variety to another were noted.

The lack of an internal layering in some of the bodies is attributable to severe post-mineralization faulting localized within the alteration zone. The relative homogeneity of most of the unlayered deposits, however, appears to be a primary feature.

In most of the layered deposits that lie directly above the diabase sill, the layer next to the diabase consists of thinly laminated rock in which either talc or tremolite predominates. The laminated layer is ordinarily from 5 to 15 feet wide and generally occupies from one-fifth to one-half of the width of the body.

The laminated layer ordinarily is bordered by an outer layer of schistose or massive rock which contains talc as the predominant silicate mineral. In a few deposits, however, the outer layer contains a large proportion of massive tremolite rock. A characteristic feature of the schistose outer layer is a marked pinching and swelling caused, in large part, by faulting localized by the physical weakness of talc schist. In several deposits, especially in the bodies of the Western mine, the outer layer contains abundant inclusions of dolomite and the brown silicate-carbonate rock, a feature not shown by the laminated layer.

Most of the more tremolitic bodies, including those at the Western (figs. 3 and 17), Acme, and parts of the Excelsior (pl. 1C) and Atlas deposits, show two layers of white rock for most of their lengths. In each of these, the thinly laminated layer next to the diabase is highly tremolitic whereas the outer layer consists mostly of talc schist. In such bodies, even though tremolitic masses exist within the outer layer, the outermost several feet are markedly tremolite-poor.

Some of the talc-rich, tremolite-poor deposits also show the two-layered structure. In these, both the thinly laminated inner layer and the outer layer are highly talcose and contain a very subordinate to negligible tremolite fraction. The Eclipse deposit (fig. 9) and most of the bodies in Warm Spring (pl. 1B) and Galena Canyons (pl. 1A) are of this type. At these localities, the textural features, both megascopic and microscopic, of the thinly laminated talc rock, are nearly identical with those of the thinly laminated tremolite rock observed elsewhere, the talc occurring in blades typical of the habit of tremolite. These talc-rich layers, therefore, appear to have originally consisted of laminated tremolite rock and to show a nearly complete replacement of tremolite by talc.

The Superior deposit (fig. 16) is unusual, not only because it is the largest of the known commercial bodies that lie beneath the lower sill, but also because, for a lateral distance of about 700 feet, it consists of three layers (Wright, 1952). The inner and outer layers each average more than 15 feet wide, and consist mostly of a fine-grained foliated talc rock. Much of the rock in the layer next to the diabase, like that of the inner layer of the two-ply deposits, is thinly laminated. The center layer is about 40 feet thick and consists of a mixture of tremolite and carbonate material. It has not been mined.

Most of the talc-rich bodies that consist almost wholly of one variety of the white rock are separated from diabase by a layer of quartzite or by other alteration rocks. Such bodies are contained in the Crystal Spring and Smith (pl. 1A, fig. 24), Ibex (fig. 18), Rainbow (fig. 23), White Cap, Excelsior (pl. 1C), and Owlshead deposits. Most of these are composed predominantly of talc schist; locally they contain massive talc rock and massive tremolite rock. The deposit at the Rainbow mine consists of layers of massive tremolite rock that lie 20 to 50 feet above the upper margin of the Ibex sill and is underlain by the above-mentioned layer of green tremolitic rock.

Several of the deposits that are in contact with diabase are composed mostly of talc schist. These include the Monarch and Pleasanton (fig. 20) and parts of the Markley and Atlas deposits. The Montgomery deposit, which extends laterally from a diabase dike that cuts the carbonate member, is composed mostly of massive talc rock. The Pongo deposit, also in contact with diabase, is composed of laminated talc rock for its entire 15-foot thickness.

TYPES OF COMMERCIAL TALC

Laminated rocks. The thinly laminated rocks, so common in the inner parts of numerous deposits that lie next to diabase, are persistently compact, white, and fine grained. Both the tremolitic and talcose varieties ordinarily contain from 2 to 15 percent of carbonate material (probably a mixture of calcite and dolomite). One or more minerals of the chlorite group form the only other common silicate material.

Individual lamellae are of strikingly uniform width, mostly within the 0.1 to 0.2 mm. range, and are so planar and continuous that they closely resemble sedimentary strata. Of the laminated rock observed in thin section, the chloritic material composes as much as 20 percent but averages only a few percent. On weathered surfaces of the tremolitic rock (photo 1), some of the lamellae are accentuated by a brownish stain. Weathered specimens of the tremolitic rock characteristically spall into paper-thin layers; but, where unweathered, both the talcose and tremolitic varieties break into much thicker, platy slabs. At a few places, especially along the most northerly talc body on the Atlas property, laminated tremolite rock grades laterally into thin-bedded dolomite so that here the lamellae do indeed appear to be relict strata.

Thin section studies show that adjacent lamellae differ from one another mainly by differences in grain size. Both talc and tremolite occur in grains that range in outline from stubby and shredlike to acicular. Most are between 0.01 mm. and 0.2 mm. long; grains from 0.2 mm. to 2.0 mm. long commonly compose individual laminations. Although the similarity in habit suggests that the talc is pseudomorphic after tremolite, the intermediate stages of replacement were not observed.

Photo 1. Laminated tremolitic rock at Western mine.

Most of the talc and tremolite grains occur, with no apparent preferred dimensional orientation, in mesh-like aggregates; but some of the more pronounced lamellae contain relatively large grains that lie normal to the foliation planes. Others contain talc grains dimensionally aligned with the bounding planes.

The carbonate grains range in outline from equant to markedly elongate. Most have maximum dimensions in the 0.02 to 0.4 mm. range. In some of the observed specimens, carbonate grains are evenly disseminated through the rock, either singly or in mosaic-like clusters. In others, carbonate grains are concentrated along individual lamellae. Much of the carbonate material, however, occurs in minute veinlets and lenticles, some of which are also quartz-bearing. Most of these lie parallel with the laminations, but others are cross-cutting features. The disseminated carbonate grains ordinarily are corroded or transected by aggregates of talc or tremolite. The veinlets appear to postdate the talc and tremolite.

Some specimens show a relatively even distribution of chlorite grains; in others, the mineral is confined mostly to individual lamellae. The chlorite grains show two habits, one plumose or feathery, the other shredlike. Maximum grain dimensions in the range of 0.05 mm. to 0.5 mm. are characteristic of both habits. Both have formed at least partly at the expense of tremolite and carbonate and have been partly replaced by talc.

Some of the specimens are clouded with several percent or less of pale brown material that is two fine grained to be identified with the microscope. This material also varies in abundance from lamellae to lamellae. Opaque particles, consistently less than 0.01 mm. in diameter, are ubiquitous. Although present only in traces, they also range markedly in abundance. Quartz, present in traces, occurs only in lenticles or late-stage veinlets, and, as previously indicated, is commonly associated with carbonate material. In most specimens quartz was not observed. Sphene was noted in very sparsely scattered grains. Although feldspar was not observed, should it occur in minute grains and in traces, it easily could have escaped detection.

Massive rocks. In outcrop, the massive varieties of talc-tremolite rock are distinguishable from the laminated and schistose varieties mainly by their tendency to break into tough and equant rather than relatively fragile and tabular fragments. The massive rocks do, however, have a crude planar structure featured by lenticles and layers, in subparallel arrangement and with contrasting textures and mineral content. In the several thin sections examined, most of the silicate grains are shown to be in mesh-like aggregates or in radial clusters, but relatively common are layers in which grains lie roughly normal to the planar structure. As in the laminated rocks, the carbonate material is disseminated in single grains and in grain clusters, and also occurs in minute veinlets, variously oriented with respect to the planar structure. In thin sections of specimens intermediate between massive and schistose, most of the talc shows a dimensional parallelism, and most of the tremolite lies athwart the schistosity.

The following are microscopic textural patterns typical of the massive rock: (1) very fine-grained, decussate aggregates of talc, of tremolite, or of a mixture of both; (2) aggregates similar to the above in grain size and mineralogy, but composed largely of clusters of radiating grains; (3) matrices that resemble type 1 or 2, but containing knots or elongate lenses of distinctly coarser-grained tremolite, or intertonguing with irregularly-shaped aggregates of chlorite; (4) decussate tremolite (?) aggregates forming cloudy, brownish masses embayed and traversed by talc-chlorite veinlets, and (5) brownish masses composed mostly of radiating blades of chlorite in a much finer-grained talc-tremolite-chlorite matrix.

Except for the differences in fabric, most of the microscopic features of the massive rocks are similar to those of the laminated rocks. This is true of the habit and grain sizes of the talc, chlorite, carbonate, and much of the tremolite. The occurrence and proportions of such minor constituents as the opaque grains, quartz, and sphene are likewise comparable. In individual specimens of the massive rock, however, the average tremolite grain is generally several times longer than the average talc grain.

As in the laminated rocks, most of the disseminated carbonate grains or grain clusters are corroded or cross-cut by aggregates of talc or tremolite, which are in turn cut by later carbonate veinlets. Textures that clearly show age relations between the silicate minerals are uncommon. Talc locally appears to be pseudomorphic after tremolite; tremolite blades also have been replaced by finer-grained aggregates of talc. In the massive rocks, also, at least part of the chlorite has replaced tremolite, and part of the talc has replaced chlorite.

Schistose rocks. The schistose variety of white rock differs from the laminated and massive varieties mainly in that most of its contained talc grains are dimensionally aligned, a feature that suggests formation under stress. Also characteristic of the schistose rock is the persistence of a very high talc-to-tremolite ratio. In most of the schistose specimens examined in thin section, tremolite is missing altogether. Where present, the tremolite blades ordinarily lie in various positions athwart the schistosity and appear to be residual from a pre-schist fabric. Most of the tremolite blades are several times longer than the aligned talc shreds with which they are associated. These features cause most of the schistose rock to be soft and friable in contrast with the tough and platy or blocky nature of the other varieties.

The schistose rock, however, shares many of the features of the laminated or massive varieties. Like them, it is white or nearly so, and is generally fine grained. Its principal constituents are talc, tremolite, chlorite and carbonate; but, of these, only talc was observed in all of the thin sections. It also contains minor proportions to traces of the opaque grains, quartz, sphene, and the sub-microscopic, cloudy material.

Talc in some large masses of schist occurs in pearly, curved, micaceous flakes as much as one cm. in diameter; but it is generally very fine-grained and aggregates are chalky in appearance. Thin section studies show that the finer grained talc occurs in grains mostly less than 0.2 mm. long. In aggregate these grains extinguish nearly simultaneously over large parts of single thin sections, and give the appearance of much larger individual grains.

Carbonate material composes at least 2 percent of most of the thin sections examined, and as much as 50 or 60 percent of some. As in the other varieties of the white rock, the diameters of individual carbonate grains are generally in the 0.02 to 0.4 mm. range, and the grains are distributed singly, in clusters, and in veinlets. Most of the clusters are markedly elongate parallel with the schistosity. The veinlets also generally are parallel with the schistosity, but some lie at high angles across it. The disseminated grains and clusters are commonly corroded and traversed by talc aggregates; the veinlets appear to post-date the talc.

The chlorite, like the tremolite, is generally rare or absent in the thin sections examined but composes as much as 20 percent of some. It occurs in irregular knots and lenticles that appear to be corroded by talc and are commonly cross-cut by streaks of aligned talc shreds.

Other Silicated Rocks

BROWN SILICATE-CARBONATE ROCK

Brown silicate-carbonate rock, as previously noted, characteristically occurs as a layer at or near the margins of the larger bodies of white alteration rock that lie along the upper margin of the lower sill. Such a layer commonly separates a layer of white rock from unsilicated carbonate strata or lies between two layers of white rock. Layers of the brown rock are particularly well-developed at the Rogers, Western, Acme, Ibex, Monarch and Grantham mines, and range in thickness from a few inches to 12 feet. Their contacts with talc-tremolite rock are very sharp, whereas contacts with carbonate strata are gradational.

At the Western mine, brown alteration rock forms an outer border with an average thickness of nearly 10 feet. This deposit also contains bodies of the brown rock, as much as eight feet thick and several tens of feet long, that interfinger with talc schist and form elongate inclusions within the schist. Some of the inclusions are rimmed with an irregular and discontinuous border of pale gray dolomite as much as one foot thick. The dolomite rims are persistently thicker along the bottoms of the inclusions than along the tops. At several places, veinlets of white talc-schist, as much as a foot wide, extend into the bordering layer of brown rock.

Examination of several thin sections of the brown rock shows that it is composed of minute lenticles and veinlets, in semiparallel arrangement, generally less than 2 mm. wide, and of contrasting mineralogy. Some of the lenticles consist mainly of magnesium silicate minerals, others of very fine-grained quartz, still others of carbonate, albite and quartz. Age relations between the minerals are not well shown. Some of the chlorite appears to be pseudomorphous after tremolite; much of the talc, feldspar, quartz and carbonate occurs in the veinlets which post-date the material in the lenticles.

Chemical analyses of two specimens of the typical brown silicate rock (table 3) are notably higher in CO_2, Al_2O_3 and K_2O, and lower in MgO than analyses of typical white magnesium silicate rock. The former also are somewhat richer in iron oxide and Na_2O. The high Al_2O_3 and K_2O percentages suggest that much of the untwinned alkali feldspar is orthoclase, and that much of the micaceous material is potassic. The mineral composition of the brown rock varies so greatly from place to place, however, that the two analyses may not be representative.

GREEN TREMOLITIC ROCK

Unlike the white talc-tremolite rock, the larger bodies of which are restricted to alteration zones associated with the lower diabase sill, the green tremolitic rock occurs in alteration zones along the higher sills as well. It also composes most of the material in the septa within the Ibex and higher sills. In some localities, including the Excelsior, Superior, Grantham and Death Valley mine areas, a relatively large part of the contact zone that borders the lower sill is of the green tremolitic rock; but at most places, the sill is associated with little or none of the green rock. Conversely, most of the silication associated with the higher diabase bodies has yielded green tremolitic rock.

Where the green tremolitic rock and the white magnesium silicate rock exist in the same alteration zone, the two generally form layers from several inches to several feet thick, with contacts ranging from very sharp to gradational through several inches. These layers, like those within the individual bodies of white rock, are essentially parallel with the bedding of the nearest unaltered sedimentary rocks. The contacts between green tremolitic rock and unaltered carbonate strata also range from sharp to gradational through several inches.

The green tremolitic rock is compact, very fine grained, and characteristically breaks into evenly-layered slabs from a fraction of an inch to several inches thick. The pale green is the most characteristic color, but a pale bluish gray shade also is quite common. The rock appears persistently to maintain these general megascopic features regardless of the proportions of other constituents.

Each of ten thin sections of representative specimens of green tremolitic rock contains an appreciable, but non-uniform, proportion of tremolite. Tremolite locally composes almost all of the rock. Alkali feldspar (apparently both sodic and potassic varieties) generally is present in fractions of from one-fourth to three-fourths.

Each section also contains from a trace to several percent of finely divided, opaque and semi-opaque material. Carbonate grains form as much as 30 percent of the sections; but in two sections no carbonate was noted. Diopside occurs in two of the sections, and forms about 20 percent of the rock in these. Quartz, although difficult to distinguish from untwinned feldspar, probably constitutes no more than 5 percent of any section. Relatively rare constituents are actinolite and chlorite. The latter appears to have replaced tremolite.

Silicate and quartz grains generally are from 0.01 mm. to 0.2 mm. in diameter. The carbonate grains range from about 0.01 mm. to about 2.0 mm. in diameter. The opaque and semi-opaque particles rarely exceed 0.01 mm. in diameter.

Each section shows a relatively homogeneous texture featured by an even distribution of tremolite needles. Some of the needles are in jackstraw arrangement; others are in radial clusters that extend outward from common centers, or inward from the margins of feldspar or quartz grains. The feldspar and quartz also are uniformly disseminated through the rock, and, where in excess of tremolite, form an even-grained mosaic.

The carbonate grains are disseminated and show very irregular outlines caused by a corrosion and transection by aggregates of tremolite, feldspar, and quartz. These grains appear to be remnants of an original crystalline carbonate rock. The diopside, as observed in thin section, is largely confined to irregular masses and shows no well-defined replacement textures with the other constituents.

Minute opaque and semi-opaque particles are rather evenly distributed through the rock, but commonly cluster in clots interstitial to grains of the other minerals.

Chemical analyses of two representative specimens of green tremolitic rock (table 3), compared with analyses of the white rock (table 2), show that the former are distinctly more aluminous and potassic, and much less magnesian, than the white rock.

Genesis of the Silicated Zones

Evidence, already cited, has led to the conclusions that (1) the silicated zones are of contact metamorphic origin and formed concurrently with the intrusion of diabase bodies, (2) they are alterations of carbonate strata mostly of dolomitic composition and commonly silicious, (3) all of the bodies of commercial talc represent an enrichment in MgO, (4) silica was introduced into at least some of them, (5) the variations in chert content of the original carbonate rock had little, if any, influence on the ultimate proportions of talc and tremolite in the silicated zones, and (6) the silication occurred in Precambrian time under a sedimentary load now represented by strata no more than 2500 feet in total thickness and perhaps only a few hundred feet thick. Moreover, the suggestion is strong that the strata into which the diabase was intruded were poorly consolidated and saturated with marine water.

Among numerous questions, the answers to which are only suggested by the available data or remain purely speculative, are the following: (1) why have the largest and most thoroughly silicated zones formed at the base of the carbonate member, whereas, higher in the member, diabase contacts commonly show little or no silication; (2) why are all of the large bodies of white magnesium silicate rock and brown silicate-carbonate rock restricted to these lower zones, and the bodies of green tremolitic rock distributed throughout the member; (3) why are some bodies of white magnesium silicate rock composed of the same rock type, whereas others consist of layers of contrasting mineralogy and/or texture; (4) how did the original carbonate rocks become enriched in MgO and SiO_2; and (5) under what conditions of temperature and pressure did the silication occur?

(1) Although stratiform in appearance, the zone of silication at the base of the carbonate member does not appear to have been localized by physical and/or chemical properties peculiar to the original basal strata. Where these strata remain unaltered (in the absence of the diabase), the lithologies are sufficiently typical of the rest of the member to justify the assumption that the now silicated strata were once very like the beds immediately above. Likewise, the general uniformity of the diabase composition throughout the Crystal Spring Formation precludes an association of the lower zone with a peculiar phase of the diabase.

Instead, the localization of the zone seems best attributed to its position along a major and region-wide lithologic interface, between the carbonate member and the underlying non-carbonate clastic units. Here the clastic units may well have provided a more abundant source of water and, perhaps, of silica than was available in the higher parts of the carbonate member. Under these conditions, the heat provided by the diabase may have been the only other requirement to produce the altered rocks typical of the lower zone. The barrenness of many of the higher diabase-dolomite contacts could, therefore, be attributed to the sparsity of water or of available silica, or both.

(2) The green tremolitic rock, being poor in talc and the other hydrous minerals that characterize the lower zone, thus would have formed in the relatively dry environment suggested above for the interior of the member (where most of the green rock occurs). As the alkali feldspars show a wide range in abundance, but are evenly distributed within individual masses of the green rock, they appear to reflect the presence of impurities in the original strata. In the lower zone, on the other hand, the alkali and aluminum bearing minerals are concentrated in the brown silicate rock. They, therefore, characterize the upper parts and especially the outer margin of the zone and are generally missing in the white rock which lies nearer the diabase contacts. The suggestion is strong, therefore, that in the relatively wet environment visualized for the lower zone, the alkalies and alumina moved outward from the diabase and/or the strata being altered to the white rock.

(3) The two-ply structure, so common in the bodies of white magnesium silicate rock that overlie the diabase sill, appears to be an effect of the contact metamorphism, as the thinly laminated layer everywhere is in contact with the upper margin of the sill and the massive to schistose layer composes the outer part of the body. The laminations bear such a striking resemblance to paper-thin strata, that they were first believed to be relict bedding, an interpretation that later seemed unlikely when strata of such thinness were found to be uncommon in the unaltered carbonate beds and, not even the outlines of the chert lenses were seen in the textures of the silicated rock. Subsequently, however, at the most northerly body on the Atlas property, the writer has observed a lateral transition from laminated rock into thin strata of carbonate, and now again is inclined to the relict strata interpretation, and to the possibility that, at the time of the silication, all of the lower part of the carbonate member was thinly bedded, the preservation having been more effective in the silicated rock than in the unaltered rock. If so, we must conclude that chert if originally present in the now silicated rock also was then thinly bedded.

As both the highly tremolitic and highly talcose varieties of the laminated rock are identical in texture, and as the talc shows the bladed habit of tremolite and is apparently a replacement of it, the laminated rock appears to represent intensive tremolitization in a well-defined layer along the upper margin of the diabase. This layer presumably formed under higher temperatures than the outer layer, in which tremolite is much less abundant and in which most of the talc seems to have formed at the expense of carbonate material.

There is also, however, a strong suggestion of an original stratigraphic control on the distribution of the white and brown rocks in such deposits as those in Warm Spring and Galena Canyons where the two are evenly and persistently interlayered. Here, any outward-moving alumina and alkalies may have become concentrated in layers with a comparitively high original content of aluminous minerals.

(4) As shown in table 2, the white rock that has been mined as commercial talc shows certain persistent chemical characteristics, notably MgO contents of 25 to 30 percent by weight, Al_2O_3, K_2O and Na_2O contents of generally less than 2.5 percent each, iron oxide contents consistently less than 1 percent, and typical water of crystallization contents of 3 to 4 percent. The rock, therefore, contains at least 6 to 12 percent more magnesia than ideally pure dolomite, and is distinctly

poorer in alkalies, alumina and iron than the other types of silicated rock in the carbonate member (table 3).

The enrichment of the carbonate strata in MgO does not seem attributable merely to the removal of CaO and CO_2 during the alteration of dolomite as this would require reductions in volume incompatible with field relations and would involve an excess of silica in the alteration of the more cherty dolomites. In the few places where unaltered strata were observed to extend laterally into silicated zones, they do so without detectable disturbance of the bedding and suggest volume-by-volume replacement. Moreover, free silica is rare in the rock that appears to have formed at the expense of cherty dolomite.

Additive MgO could have been received from other strata, the water trapped in them, the diabase or combinations of the three. As the diabase bodies, at least locally, contain the border zones that appear to have been enriched, rather than impoverished, in MgO and also show the barren contacts with dolomite, the available evidence points against them as a major source.

The abundance of dolomite in the carbonate member indicates that the later Precambrian seas were highly magnesian, but the volume of ground water involved could not have been great enough to cause the indicated 6 to 12 percent MgO enrichment through thicknesses of 15 to 100 feet of dolomite and an even greater MgO enrichment in the alteration of cherty dolomite.

Neither is there clear evidence of the derivation of MgO from magnesium-rich sedimentary rocks elsewhere in the section. The virtual absence of such rocks in the various Precambrian units beneath the carbonate member seems to eliminate the possibility of an upward migration of MgO derived from lower units. The carbonate member itself, although close at hand, shows no signs of dedolomitization that can be related to the formation of the talc- and tremolitic-bearing zones.

Although but two analyses of the brown border rock are available, these average only about 11 percent MgO and suggest the possibility that magnesium moved from the original dolomite toward the diabase contact, while alkalies in the original dolomite near the contact moved outward. It is possible, too, that magnesium was derived from even greater distances within the dolomite and that no evidence remains of this transfer. A rigorous consideration of the problem is hindered by a lack of experimental data on the migration of magnesium and alkalies through carbonate rocks. Obviously further study, involving additional petrographic, and geochemical data, is required.

The source of the additive silica, of easier explanation, could have been the siliceous strata that underlie the carbonate member or the now silica-poor border zone of the diabase sill or both.

(5) The highest temperatures that could have pertained during the alteration would be the maximum ascribed to diabase magmas or about 1100°C. But the abundance of phenocrysts in the chilled margins of the sills suggests that its temperature was considerably below this figure. Relatively low temperatures also are suggested by the persistent association of calcite and tremolite in all three varieties of silicate rock. These two are diagnostic of the fourth of Bowen's thirteen steps in the progressive metamorphism of siliceous dolomite (Bowen, 1940, p. 257). Bowen's work suggests that at all pressures lower than 1500 atm., and in the absence of other minerals more magnesian than dolomite, calcite and tremolite can exist in equilibrium only at temperatures lower than 650°C.

If the diabase was intruded under a load composed of sediments 1000 to 3000 feet thick plus a column of seawater which sedimentary structures and algal remains suggest was seldom more than a few tens of feet deep, the confining pressure probably did not exceed 500 atmospheres, even if 100 to 200 atmospheres of pressure was produced by CO_2 released during the silication.

The carbonate-tremolite-chlorite-talc sequence (each having formed at the expense of each mineral listed before it) probably represents a period of declining temperature and pressure. That the tremolite formed under the highest temperatures of metamorphism and talc under the lowest is suggested by the persistent occurrence of the highly tremolite rock in a layer adjacent to the diabase and by the concentration of talc, as a direct replacement of carbonate, in an outer layer. The highest pressures appear to have pertained during the maximum release of CO_2 when, in the typical deposit, tremolite was forming nearest the diabase contact and the talc was forming in the outer part of the zone. The mineral sequence also indicates that the enrichment in MgO and SiO_2 and the removal of CaO and CO_2 was a continuing process.

That stress was a factor in the formation of the talc schist is shown by the local occurrence in the schist of earlier blades of tremolite with no pronounced dimensional alignment. As talc grains commonly show no preferred orientation in other alteration rocks, a stressed environment does not seem necessary for the formation of talc.

DESCRIPTIONS OF TALC–BEARING AREAS

Southeastern Panamint Range. The most westerly talc deposits in the southern Death Valley region, as well as the most westerly of the known occurrences of the Crystal Spring Formation, are exposed within an area of about 25 square miles on the east slope of the southern part of the Panamint Range. This area includes the lower parts of Anvil Spring, Warm Spring, and Galena Canyons which drain eastward into Death Valley. It contains the Grantham, Death Valley, Bonnie, and Montgomery mines, and several prospects. Water for the mining operations is obtained from Warm Spring in Warm Spring Canyon and Galena Spring in Galena Canyon.

In this area, the Crystal Spring Formation rests, generally with depositional contact, upon earlier Precambrian gneiss and schist (Wasserberg, Wetherell, and Wright, 1959). The Crystal Spring Formation is here about 4000 feet thick and contains all of the members already described as typical in the region to the east-southeast. As this is nearly a maximum thickness and as the strata show no marked change in facies from east to west, one can assume that the formation

Photo 2. Aerial view southward of southeastern part of Panamint Range, showing lower parts of Warm Spring Canyon (foreground) and Anvil Spring Canyon (mid-distance). Exposures of talc-bearing zone at Grantham mine, exposed low along near canyon walls, are overlain by carbonate member (light-colored exposures) and diabase (dark exposures) of later Precambrian Crystal Spring Formation. Tertiary volcanic rocks (mostly andesite) underlie crest of ridge and rest with depositional contact upon older rocks.

once extended much farther westward, and one is puzzled by the absence of clearly correlative strata and of talc and diabase bodies in the Precambrian units that are so extensively exposed along the west face of the Panamint Range. That the Crystal Spring Formation was eroded from the areas to the west is suggested by the presence of an angular unconformity between it and overlying Kingston Peak (?) strata in the upper part of Warm Spring Canyon (Chester T. Wrucke, personal communication, 1960).

The Noonday Dolomite, at least 1000 feet thick, also rests unconformably upon the Crystal Spring Formation and is exposed along the crests of the ridges in the talc-bearing area. Landslide masses composed wholly of Noonday Dolomite are common within the area and easily can be mistaken for dolomite in place.

Tertiary volcanic rocks composed mostly of flows and pyroclastic layers, and generally andesitic in composition, also cap the ridges on both sides of Warm Spring Canyon and cover much of the talc-bearing zone at this locality.

In the southeastern Panamint Range, the largest and most productive bodies of talc—the principal bodies at the Grantham and Death Valley mines—have altered from siliceous dolomite at the base of the carbonate member and lie along the upper margin of a diabase sill. Part of the talc at the Panamint mine also occurs in this setting. Other talc bodies at the Panamint and Grantham mines, as well as the bodies at the Bonnie mine and Timmy prospect, form parts of septa within the sill. Some of the talc bodies at the Death Valley mine lie beneath the sill.

The rocks of the southeastern slope of the Panamint Range are cut by numerous faults, of which most trend northward to northwestward. Some are normal and some are reverse or thrust faults, but, along nearly all of them, the east (valley) side has moved down with respect to the west side. The principal faults have broken the rocks of the Crystal Spring Formation into slices which, in general, are several thousand feet long and several hundred feet wide (pls. 1A and 1B).

Within these slices, the units of the Crystal Spring Formation dip gently to moderately eastward to southeastward. The mineable talc bodies, which ordinarily are fault-terminated, range in length from a few tens of feet to 2000 feet or more.

Owlshead Mountains. On the northeast edge of the Owlshead Mountains, which form part of the west margin of southern Death Valley, sedimentary units and diabase bodies of the Crystal Spring Formation dip moderately and uniformly to the northeast. Near the crest of the range, quartzite of the lower part of the formation is in intrusive contact with Mesozoic (?) quartz monzonite which underlies most of the Owlshead Mountains. The remainder of the exposed part of the Crystal Spring Formation consists mainly of unusually thick sills of diabase. Along the base of the lowest sill, and about 2500 feet above the floor of Death Valley, carbonate strata have been altered to bodies of talc and tremolite which are known as the Owlshead deposits and are described in the section on individual properties.

Talc Hills. The Talc Hills, at the southern end of the Black Mountains and lying between the Ibex Hills and southern Death Valley, trend northward and consist mostly of earlier Precambrian schist and gneiss. Along their east side is a narrow, east-dipping and highly faulted belt of younger rocks composed largely of the sedimentary units and diabase of the Crystal Spring Formation. Discontinuously exposed fault blocks of Beck Spring Dolomite and Noonday Dolomite rest upon the Crystal Spring units. This belt, which is about 6 miles long and one quarter of a mile to one mile wide, is bordered on the east by Tertiary volcanic rocks and Quaternary alluvium.

In the southern part of the Talc Hills, the Crystal Spring Formation rests upon the older rocks with a depositional contact; in the northern part of the hills, the contact is a low-angle fault. This fault and the overlying plate has been likened to, and tentatively correlated with, the Amargosa thrust and chaos as exposed in the Virgin Spring area about ten miles to the northwest (Noble and Wright, 1954).

The exposures of the Crystal Spring Formation in the Talc Hills contain all of the units previously described as characteristic. They show approximately normal thicknesses, although, in some places, large parts of the Crystal Spring section have been cut out by faults that are approximately parallel with the bedding.

The known bodies of commercial talc in the Talc Hills are confined to a 3¾-mile strip of Crystal Spring exposures in the northern part of the hills. Here, as elsewhere, virtually all of the alteration to magnesium silicate minerals has been localized in the lower strata of the carbonate member and is associated with a diabase sill intruded at or near the base of the member.

For many years all of the known talc deposits in the Talc Hills have been covered by a single group of claims. They formerly were known either as the "Valley" or "Brown" deposits, but in recent years the present owner has referred to them as the Atlas deposits which is the name used in this report. In mid-1960, no talc had been shipped from them, but two of them were being readied for mining operations.

Ibex Hills. In the Ibex Hills, which form part of the east side of the Amargosa Valley and are 15 miles long, the Crystal Spring Formation is widely exposed and talc deposits are numerous. In the southern part of the hills is an east-tilted fault block, about three miles long, the eastern face of which consists almost wholly of the middle and lower units of the Crystal Spring Formation (photo 3) (i.e. the lower quartzitic and shaly members, a diabase sill and the carbonate member which here consists of chert-free dolomite and limestone). In this area the Crystal Spring Formation rests with depositional contact upon earlier Precambrian metamorphic rocks. A talc-bearing zone borders the upper margin of the sill. All of the talc produced from this zone has been obtained from the Ibex (Moorehouse), and Monarch mines at the southern end of the fault block. Water for these mines is obtained at Ibex Spring at the southern end of the hills.

Talc deposits, in a similar stratigraphic setting, are exposed on the east slope of the central part of the Ibex Hills. In this area the Crystal Spring Formation occurs, with other formations of later Precambrian and Cambrian age, in a structurally complex terrane which has been identified with the Virgin Spring chaos as defined by Noble (1941). The chaos of the central Ibex Hills consists essentially of numerous, east-dipping imbricate slabs which rarely exceed half a mile in width. The talc deposits that exist in these slabs, therefore, are generally less continuous and more highly faulted than most of the others in the region. Nevertheless at one mine, the Eclipse, a large talc body has been worked nearly continuously for many years. Several other deposits, including the Mammoth, Jim Francis, Arletta, and Markley have been mined briefly or thoroughly prospected.

Saratoga Hills. The Saratoga Hills, which trend northward and are about four miles long, form a southern extension of the Ibex Hills and are almost surrounded by alluvium. They consist, in general, of an east-tilted block composed mostly of a little-disturbed and nearly complete section of the Pahrump Group (Wright, 1952). Along the west side of the hills are local exposures of the underlying earlier Precambrian metamorphic rocks, whereas patches of Noonday Dolomite overlie Pahrump units on the crest and northeastern part of the hills, and shallow dunes obscure bedrock over much of the northern part.

The Crystal Spring Formation is extensively exposed on the western slopes of the hills. It is only about 2300 feet thick, but contains all of the characteristic members as well as a diabase sill near the base of the carbonate member. The carbonate strata have been altered to magnesium silicate minerals both above and below the sill and in septa within it. This talc-bearing area is unusual, for, at the Superior mine, it contains a large, thoroughly silicated body of commercial rock that lies beneath the sill, whereas the silication in the zone above the sill is much less pronounced, and the rock remains unmined. The Superior mine has been by far the most productive talc operation in the Saratoga Hills, but three much smaller mines—the Pongo, Saratoga, and White Cap—have been worked intermittently. The deposits at these three and at several prospects occur in septa within the diabase sill.

Photo 3. View northward of Ibex Hills. Feldspathic quartzite member of later Precambrian Crystal Spring Formation underlies crest of hills and rests with depositional contact upon earlier Precambrian metamorphic rocks to left. Ibex sill (diabase) forms continuous dark band low along east slope, dips steeply eastward. Purple shale and fine-grained quartzite members underlie intermediate slopes.

Saddle Peak Hills. The Saddle Peak Hills, like the Saratoga Hills just west of them, are a north-trending, east-tilted block composed mostly of units of the Pahrump Group, capped and flanked on the northeast by Cambrian (?) sedimentary rocks, and almost surrounded by alluvium. Although the hills are about eight miles long and three miles in maximum width, exposures of the Crystal Spring Formation are limited to a narrow band, about three miles long and low on their southwest flank. Alluvium and dune sand everywhere hide the base of the formation and northward overlap successively higher Crystal Spring units to a point where the entire formation is covered.

Although thus incompletely exposed, the Crystal Spring Formation here contains a carbonate member, apparently in its middle part, at or near the base of which is a diabase sill. Along the upper margin of the sill, and in septa within it, the carbonate rock has been partly altered to aggregates of magnesium silicate minerals which locally have proved to consist of commercial talc. The bodies of altered rock have been noted along a lateral distance of about two miles, and similar bodies probably lie hidden beneath the alluvium that flanks the west side of the hills. Within this talc-bearing belt are two mines, the Rainbow and Caliente (B.F.J.), both of which were opened in the mid-1950's.

Northern Avawatz Mountains. The only known talc deposits in the area of the Avawatz Mountains are in a west-trending, fault-bounded block that forms a foothill in the Sheep Creek Spring area along the north base of the mountains and lies within the area of juncture of the Garlock and Death Valley fault zones (Noble and Wright, 1954). Within this block, the Crystal Spring Formation rests with depositional contact upon granitic gneiss of earlier Precambrian age. Here, the Crystal Spring units strike westward and, generally, dip steeply northward. The quartzitic and shaly members, that are characteristic of the lower part of the formation elsewhere, are successively overlain by a diabase sill and a member that consists mostly of carbonate strata, silicated to various degrees. This member seems correlative with the carbonate member, exposed at other localities in the region, and is about 200 feet in maximum thickness. The thickest and most extensively exposed occurrence of this member, and the one that appears to contain nearly all of the mineable talc in the Sheep Creek area, extends from the west face of the canyon westward for about 1800 feet. The talc bodies associated with it have been developed by workings known collectively as the Sheep Creek mine. Water for the operations is obtained from Sheep Creek Spring about 2000 feet south of the most easterly workings.

In the area still farther to the west, only discontinuous and much thinner carbonate bodies are exposed; the diabase occurs in scattered, irregular bodies; and talc mineralization, consequently, has formed small deposits unsuited to profitable mining. Faulted segments of the carbonate member lie east of the canyon and are largely covered by alluvium. These may contain talc bodies of commercial interest, but none is presently exposed.

Alexander Hills and southern Nopah Range. The Alexander Hills, which form a southerly extension of the Nopah Range and lie east of southern Amargosa Valley, consist mostly of later Precambrian and Cambrian formations. These have been arched into a very broad, east-plunging anticline, about three miles wide and bordered on the north and south by major, east-trending faults (Wright, 1954). The more northerly of the faults occupies the gap that separates the Alexander Hills from the Nopah Range proper.

The Crystal Spring Formation, here containing all of the typical members, is exposed for a distance of about 2¾ miles along the lower part of the west face of the hills. The formation contains a talc-bearing zone which has formed along the upper margin of a diabase sill and is an alteration of cherty dolomite at the base of the carbonate member.

At the southern end of the Alexander Hills, the Crystal Spring Formation is successively overlain by the Beck Spring Dolomite and Kingston peak Formation to form one of the few essentially complete occurrences of the Pahrump Group west of the Kingston Range. From this locality, for a distance of about seven miles northward, successively lower units in the Pahrump Group are progressively cut out along the contact with the overlying Noonday Dolomite, so that in the southern end of the Nopah Range, strata of the Crystal Spring Formation wedge out northward, and the Noonday Dolomite rests directly upon earlier Precambrian metamorphic rocks.

Most of the talc that has been mined in the area of the Alexander Hills and southern Nopah Range has been obtained from two north-trending segments of the talc-bearing zone, each on the west side of the hills. The more southeasterly segment, about 1½ miles long, contains most of the workings of the Western mine (along the northern two-thirds of the segment) and those of the Acme mine (at the southern end). For a distance of about half a mile between the two mines, the zone lies unexposed and unexplored beneath Tertiary (?) fanglomerate. The other segment of the zone, which appears to be at least 2700 feet long, contains the remaining workings of the Western mine.

Photo 4. Aerial view northeastward of Alexander Hills, showing southeastern part of Western mine area. Ridge in foreground is underlain, by east-dipping units of later Precambrian Crystal Spring Formation composed, from top to bottom, of limestone and dolomite of carbonate member, talc-bearing zone (white band), diabase sill (dark band), and lower clastic units. Earlier Precambrian metamorphic rocks, in vicinity of buildings in left foreground, underlie Crystal Spring Formation along east-dipping fault contact.

Photo 5. View eastward of west side of Kingston Range, showing talc-bearing zone at Rogers mine. Cuts along lower slope of ridge on west and on higher slope in mid-distance are on segments of talc-bearing zone. These are overlain and underlain by units of later Precambrian Crystal Spring Formation. Quartz monzonite, which underlies most of range, is exposed on skyline.

Movement along a northeast-trending fault has separated the two an apparent horizontal distance of about 4000 feet so that the southern segment has moved northeastward with respect to the other.

Another talc deposit is contained in highly faulted rocks at the southeastern tip of the Alexander Hills and is the site of the Booth mine. This deposit occurs along a nearly horizontal fault-contact between earlier Precambrian metamorphic rocks and dolomite of the Crystal Spring Formation. In a similar geologic setting is the talc deposit at the Donna Loy mine, which is near the tip of the wedge of Crystal Spring strata in the southern part of the Nopah Range.

Northwestern Kingston Range. The talc deposits of the northwestern part of the Kingston Range are discontinuously exposed for a distance of six miles along the lower parts of the walls of Beck Canyon, which drains westward (pl. 1A). As shown by Hewett (1956), sedimentary units and diabase of the Crystal Spring Formation underlie most of the north slope of the canyon and much of the lower part of the south slope. Here, the units of the Crystal Spring Formation strike westward to northwestward, dip moderately to steeply northward to northeastward, and rest with a flat fault contact upon metamorphic rocks of earlier Precambrian age. These older rocks underlie areas that flank the canyon channel. Steepening of slope low on the south wall of the canyon marks an intrusive contact between the Precambrian rocks and a body of quartz monzonite which forms the main mass of the Kingston Range to the south. Water for mining is obtained from several springs within the mapped area.

The units that compose the type Crystal Spring section at Crystal Spring persist throughout the northwestern part of the Kingston Range, although most of the feldspathic quartzite member, at the base of the formation, has been faulted out at the type locality, and the carbonate member shows a marked range in thickness. In the eastern half of the mapped area, the carbonate member consists mostly of limestone rather than the characteristic dolomite. The two diabase sills, so common above and below the carbonate member throughout the region, persist here too, but locally join by cutting across the carbonate member.

Here, as elsewhere, the largest and most persistent bodies of talc have formed as alterations of the lowest strata in the carbonate member. In the lower part of the canyon, such bodies, including those at the Rogers, Smith, Omega and Crystal Spring mines, lie above the lower diabase sill but ordinarily are separated from it by a quartzite layer 10 to 50 feet thick. In the upper part of the canyon, a talc-bearing zone, covered by the Vulcan and Sam Flake mines and the Kingston prospect, lies beneath the sill. At this locality, the sill apparently was intruded slightly above the base of the carbonate member. This zone is discontinuously exposed for a lateral distance of about two miles. It remains largely unexplored, but existing exposures indicate that some segments of it are of subcommercial grade. The carbonate strata, predominantly limestone, above this part of the sill are partly altered to talc and tremolite but not thoroughly enough to constitute deposits of present commercial interest.

Near the middle of the carbonate member in the upper part of the canyon are the Beck iron deposits (Hewett, 1956; and Wright and others 1953). These consist of tabular bodies, as much as 100 feet thick, of hematite and magnetite. That the contact, at this locality, between the Crystal Spring Formation and the underlying earlier Precambrian metamorphic rocks is a low-angle thrust fault was detected in 1924, when a diamond drilling program showed that one of the iron bodies is truncated by the older rocks at depths of 450 to 600 feet.

In the present study, the trace of this fault was mapped for a distance of about two miles from the vicinity of Beck Spring westward to Crystal Spring. From east to west, this fault progressively cuts out the quartzite in the lower part of the Crystal Spring Formation, the talc-bearing zone, the lower diabase sill and the lowest strata in the carbonate member.

At Crystal Spring, the thrust fault terminates against a northeast-trending cross fault which has caused the Pahrump units on the northwest to move southwestward an apparent horizontal distance of about 4600 feet. This and three other cross faults, of 2000 to 5000 feet apparent horizontal displacement, have broken the Pahrump units, between Crystal Spring and the west front of the Kingston Range, into four slices—each within the range of half a mile to one mile wide and each containing a talc mine or prospect (pl. 1A).

Eastern Kingston Range. The talc deposits in the eastern part of the Kingston Range are in the most easterly of the known occurrences of the Crystal Spring Formation. Indeed, the entire Pahrump Group wedges out, with an angular unconformity, to the north and east beneath the Noonday Dolomite. At the northeastern tip of the Kingston Range and in the Winters Pass Hills, the Noonday Dolomite rests, apparently with depositional contact, upon metamorphic rock of earlier Precambrian age.

The observed talc alteration in the eastern Kingston Range is confined to two localities. By far the more extensive zone is that on the west slope of a north-trending ridge (pl. 1C), northeast of the main mass of the Kingston Range and about 2¾ miles east of Horse Thief Spring. This zone is continuously exposed for about 1¾ miles and has been worked by means of the long-active Excelsior mine.

A faulted segment of the talc-bearing zone is exposed at the southern end of the ridge and is the site of the Snow White mine. This segment is about 1000 feet long and is offset eastward from the southern end of the main zone an apparent horizontal distance of about 1500 feet.

In the Excelsior mine area, the Crystal Spring Formation contains all of the characteristic members. Here, however, the massive carbonate member is only about 250 feet in maximum thickness and pinches and swells markedly. Diabase occurs in three sill-like bodies; one lies within the quartzite-argillite strata in the lower part of the formation, another near the base of the carbonate member, and the other in the upper (quartzite-argillite-dolomite) strata.

In this area, as so commonly elsewhere in the region, the talc-bearing zone has formed along or close to the upper margin of the sill at the base of the carbonate member. Here, it has altered from cherty dolomite. In the vicinity of the main Excelsior workings and at the Snow White mine, however, the talc-bearing zone, although only 20 to 40 feet thick, is overlain by shale and quartzite rather than by unaltered dolomite. Thus the silication appears to have extended through the full thickness of the original dolomite.

The 1¾ mile segment of the zone, which contains the Excelsior mine workings, strikes north-northwestward and dips moderately eastward. It is offset by numerous cross faults most of which show but a few feet displacement. The smaller segment, which contains the Snow White workings strikes west-northwestward and dips moderately northward.

The other talc-bearing locality is about five miles south of the Excelsior mine and is covered by the Kingston claims. At this locality, various members of the Crystal Spring Formation are recognizable, but the carbonate member is thin and discontinuous and the talc- and tremolite-bearing rock associated with it likewise forms irregular bodies. The known exposures of these bodies are limited to a north-trending and west-dipping zone about 1,300 feet long.

Silurian Hills. The most southerly exposures of strata that can be clearly identified as belonging to the Crystal Spring Formation, occur in the western and southeastern part of the Silurian Hills. As mapped by Kupfer (1960) these hills are exceedingly complex structurally, but local exposures of the formation are relatively intact. On the western slope of the hills, exposures of the formation lie in an arcuate belt, convex eastward, about one mile long. The exposures to the southeast forms the west slope of a south-trending spur which is about half a mile long. In the Silurian Hills, the Crystal Spring Formation apparently is unusually thin and contains a higher proportion of clastic material than it does in the thicker occurrences to the north and northwest. The basal conglomerate and the feldspathic quartzite, purple shale, and carbonate members all are represented, however, and the lower sill of diabase persists in its position at or near the base of the carbonate member.

A zone of white magnesium silicate rock can be traced along or near the upper margin of the sill in most of its exposures, but this zone is generally thinner and less completely silicated than the ones elsewhere that have been extensively mined. At several places, bodies of commercial interest have been explored and two mines, the Annex and Berryhill (Riggs) have been intermittently worked. The latter, because of its proximity to the old Tonopah and Tidewater Railroad, was one of the first talc operations in the Death Valley region, being worked as early as 1911 or 1912. Talc prospects in the Silurian Hills include the Anderson, Ceramic, and Van Talc.

DESCRIPTIONS OF INDIVIDUAL PROPERTIES *

Acme mine. The name "Acme" formerly was applied to workings that now comprise part of the Western mine and also has been used as a synonym for the Amargosa mine, but since the late 1930's it generally has been restricted to a mine that lies half a mile south of the most southerly workings of the Western mine. The Acme mine area is covered by four claims,

* Since this report was written properties formerly controlled by the Southern California Minerals Company, Anchor Minerals and Chemicals, Inc., and Kennedy Minerals Company are now (1967) operated by the Minerals, Pigments and Metals Division of Chas. Pfizer & Co., Inc., P. O. Drawer AD, Victorville, California, 92394. Properties mentioned in this report include: Acme, Arletta, Bonnie, Comet, Death Valley, Eclipse, Excelsior, Monarch, Panamint, Pongo, Saratoga, Superior and White Cap.

Properties formerly controlled by Sierra Talc Company are now operated by United Sierra Division of Cyprus Mines Corporation, P.O. Box 1201, Trenton, New Jersey, 08606. Properties in this report include: Annex, Booth, Caliente, Ibex, Markley, Rainbow and Smith.

The Western Talc Company is now known as the Western Talc Division of the Vanderbilt Co., 1901 East Slauson Ave., Los Angeles.

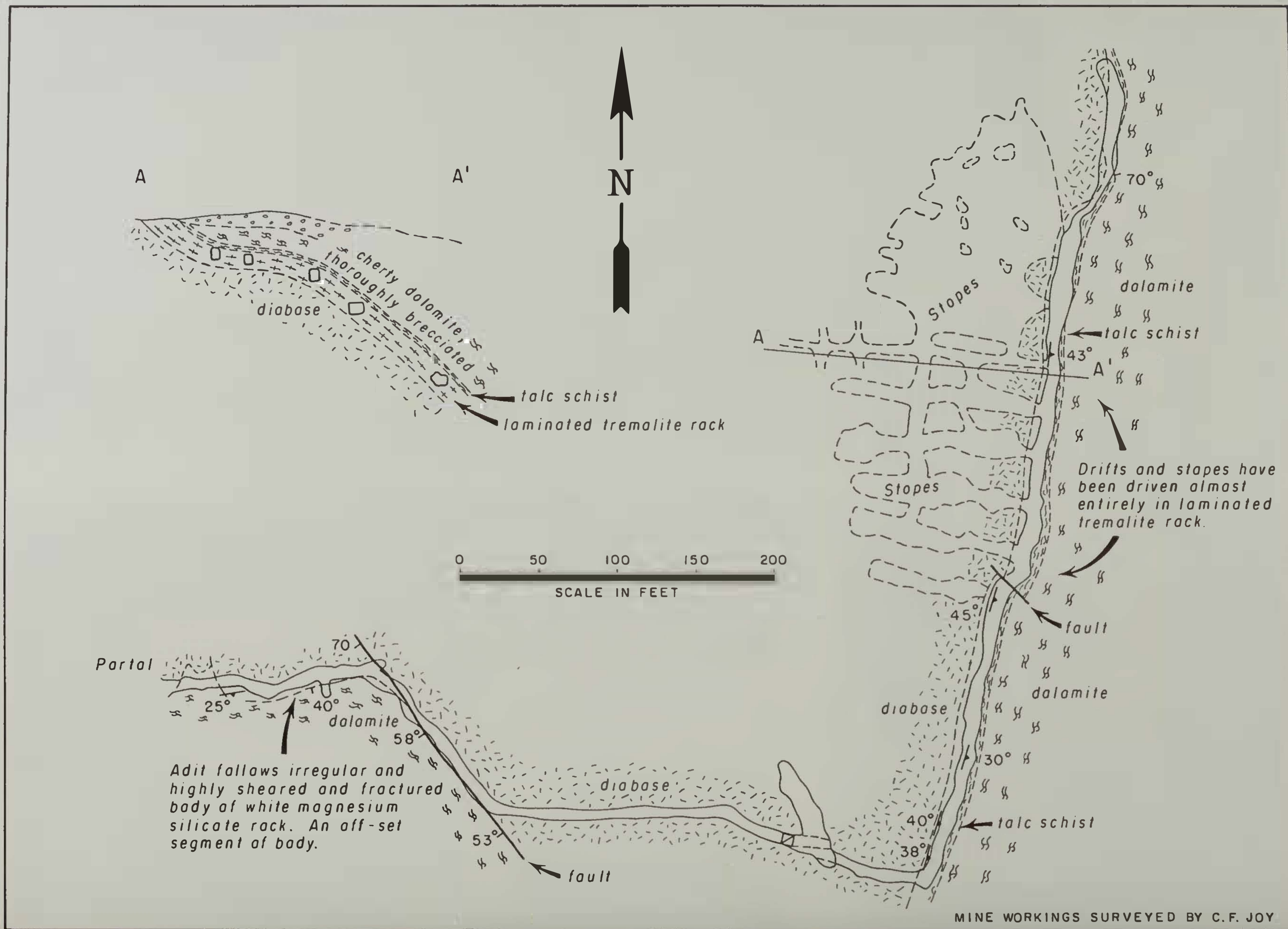

Figure 5. Geologic map of main level of Acme mine and cross section through principal talc body.

three of them patented. The claims are in secs. 4 and 9, T. 19 N., R. 8 E., S.B.M. (projected) and are owned by the Southern California Minerals Company, 321 South Mission Road, Los Angeles. This company has been the sole operator. The mine was first worked during the period 1939-44. It was reopened briefly in 1948, and, since 1951, it has been operated nearly continuously but on a small scale. Through 1959, the mine had yielded about 19,000 tons of commercial talc.

The Acme mine is at the southern end of the east-tilted fault block that contains the easternmost talc body at the Western mine (Wright, 1954). The Acme deposit, which is exposed on the sides and crest of a small, west-trending ridge, appears to be a southerly extension of the body at the Western deposit. For a distance of about 2000 feet between the two mine areas, however, the bedrock is covered with fanglomerate. In this interval the talc deposit has not been explored underground, so that the presence of mineable talc, although likely, remains undetermined.

Here, as it does at the Western mine, the talc deposit overlies a diabase sill and is overlain by dolomite of the carbonate member of the Crystal Spring Formation (fig. 5). It likewise contains a tremolitic and laminated lower layer and talcose and foliated upper layer. The tremolitic layer, in most places, is about 12 feet thick, and the talcose layer generally is two to four feet thick. As a one- to two-foot thickness of the tremolitic rock ordinarily has been left in the ceiling to prevent caving and contamination, nearly all of the mined material has been of the tremolitic rock.

The body that has yielded most of the commercial talc at the Acme mine trends about N. 10° E., toward the Western mine, and dips gently to moderately eastward. It has been followed by a drift for about 540 feet and may extend considerably to the north of the present workings. The southern termination of this body has not been encountered underground, but it apparently occurs against a northwest-trending fault within 200 feet of the southern face of the drift.

Another body, which is a segment of the same deposit has been offset to the northwest, along the fault, an apparent horizontal distance of about 400 feet. This segment strikes eastward and dips moderately southward. It is exposed underground for a lateral distance of 200 feet, but it has been made so irregular by shearing and fracturing that it remains unmined. Its most southerly underground exposures are near the major east-trending fault along the southern margin of the Alexander Hills.

The Acme deposit was first mined by means of a shaft driven from the crest of the hill and inclined gently eastward (fig. 5) on the principal talc body. It was later joined by a raise from an underground drift so that the shaft now extends for a slope distance of about 225 feet to the drift. The level, of which the drift is a part, is about 1100 feet long, and composes the longest and lowest unit of the workings. From its portal, on the southwest slope of the ridge, this level working extends as a drift for about 130 feet

Photo 6. Exposure of talc-bearing zone near entrance of Acme mine. Zone is overlain by cherty dolomite in upper part of cut and by diabase sill in lower part.

eastward along the east-trending segment of the talc deposit, to the fault that separates it from the main segment. It follows this fault contact (diabase to the north and dolomite to the southwest) southeastward for about 110 feet and thence trends about S. 80° E. for 280 feet to intersect the main talc body. From this intersection the 540-foot drift extends N. 15° E. and has been driven almost entirely in commercial talc. Most of the talc produced to date has been mined from overhand stopes extending westward from the northern two-thirds of this drift. In mid-1960 the drift is being extended still farther to the northeast. At 520 feet the talc body pinches to a thickness of about 3 feet.

Amargosa (Acme) mine. The Amargosa mine, one of the first talc operations in the Death Valley region, is about 4½ miles south of Tecopa and a few hundred feet west of the Amargosa River. Low along the east bank of the river is the grade of the now-dismantled Tonopah and Tidewater Railroad, the nearness of which was a contributing factor in the early development of the mine. Like the present Western mine, it also has been referred to as the Acme mine, but this name is now restricted to a mine one mile south of the Western mine (see Acme mine). The Amargosa mine is in sec. 34, T. 20 N., R. 7 E., and sec. 3 T. 19 N., R. 7 E., S.B.M. (projected).

Although production records are fragmental, the existing data and the appearance of the mine suggest a yield of a few thousand tons. Most of the mining was done in the period 1917–19, but local residents say that talc was shipped from the Amargosa mine as late as 1925. Most or all of the mining was done when the property was owned by W. W. Hite and Thomas Coghland. The deposit originally was covered by two claims, but in recent years little, if any work has been done on the property and its ownership status is undetermined by the writer.

The talc deposit is exposed in an inlier of Precambrian bedrock which forms part of the lower west wall of the canyon. The bedrock is surrounded by Tertiary sedimentary rocks, into which most of the canyon has been cut, and by Quaternary alluvium.

The exposed Precambrian rocks consist of dolomite, jasper, diabase and silicated rock of the Crystal Spring Formation. These are highly faulted and brecciated. The deposit consists of a single body, about 350 feet in maximum observed length and ranging from a few inches to as much as 10 feet in width. The body strikes uniformly north-northeastward and dips moderately to gently eastward. The wall rocks appear to differ from place to place and consist of thoroughly fractured dolomite, jasper, and diabase. At the surface, Tertiary conglomerate overlaps the bedrock near the west margin of the body. Fault-movement within and parallel with the body has produced a marked pinching and swelling and has caused much of the contained rock to be thoroughly crushed. The material that now remains consists mostly of friable talc schist which is commonly stained with iron oxides and interlayered with sub-commercial alteration rock.

The mine workings contain three levels, each driven from the canyon wall at vertical intervals of about 30 feet. Each of the two lower levels consists of a west-trending adit joined to drifts that extend in both directions along the talc body. In the lowest level the south drift is about 50 feet long and the north drift is inaccessible. In the second level the south and north drifts are 275 feet and 80 feet long respectively. The highest level consists of a drift adit driven south-southwestward and about 130 feet long. In each of the exposed faces on each level the talc pinches to thicknesses of a foot or less. Between levels the talc has been extensively stoped.

Annex (Mammoth) mine. The Annex mine is near the northern end of the talc-bearing zone that is discontinuously exposed for several thousand feet along the lower west face of the Silurian Hills. The deposit is covered by two claims in secs. 26 and 35 (projected) T. 17 N., R. 8 E., S.B.M. and about 18 miles north of Baker. The claims are owned by Harrison P. Gower (address: 4835 Forman Ave., North Hollywood, California) and A. L. Barton. They are leased to Sierra Talc Co., 1608 Huntington Dr., South Pasadena, California. The mine has yielded no more than 1000 tons of talc obtained mainly in the period 1940–42.

The body of alteration rock that contains the Annex deposit can be traced along the southwest slope of a northwest-trending ridge. Although this body is about 1500 feet long, and is as much as 30 feet thick, it consists mostly of green, subcommercial material. It is underlain by a diabase sill and overlain by dolomite of the carbonate member of the Crystal Spring Formation. Locally, a layer of siliceous dolomite separates the zone from the diabase. In the mine area these units strike west-northwestward and dip steeply northward. Within 100 feet down-slope from the talc-bearing zone, the lower units of the formation rest with fault contact upon older crystalline rocks. Movement parallel with this contact also has occurred within the zone and especially within the softer parts.

The mine workings have been driven along the thickest of the exposed occurrences of white silicated rock in the mine area. The talc has been removed from a lenticular bulge in a body which otherwise is very thin. The bulge is about 100 feet in horizontal dimension and 20 feet in maximum thickness. It consists mostly of well foliated talc schist, but also contains thinly laminated rock, some talc-rich and some tremolite-rich. The body contains abundant inclusions of wall-rock and is highly sheared.

It has been followed by a drift-adit, driven east-southeastward, which is about 140 feet long. A mineable thickness of talc was encountered for the first 100 feet. In the eastern part of the drift the body thins markedly. The talc has been stoped to the surface for a maximum vertical distance of about 30 feet. It remains unmined beneath the adit level. The zone of alteration also is exposed in several cuts east of and within 600 feet of the adit. Exposed in one cut, about 120 feet east of the adit, is a several-foot thickness of white tremolitic rock.

Anvil Spring Canyon deposit. On the north wall of Anvil Spring Canyon, which drains eastward from the southern part of the Panamint Range is a talc deposit that, in 1961, remains unproductive and generally unexplored. It is covered by a single claim which was located by Mr. Ernest Huhn in the late 1930's and was acquired by the present owners, the Western Talc Company, 1901 East Slauson Avenue, Los Angeles, in the early 1940's. The claim is in sec. 9, T. 22 N., R. 1 E., S.B.M.

In the area of the deposit, a bedrock composed of units of the Crystal Spring Formation, the Noonday Dolomite of Cambrian (?) age, and Mesozoic (?) granitic rock is flanked on the east by sedimentary rocks (fanglomerate and monolithologic breccia) of Pleistocene (?) age. The deposit consists of a zone of talc-bearing alteration rock the trace of which approximately coincides with the contact between the Pleistocene (?) rocks and diabase of the Crystal Spring Formation. The actual hanging wall of the zone is nowhere exposed, but lies hidden beneath the Pleistocene (?) cover.

This talc-bearing zone is exposed on the east slope of a small, south-draining side canyon. The lowest exposures of the main zone are about 200 feet above the floor of Anvil Spring Canyon. From these exposures the zone can be traced northward and diagonally upslope for about 1200 feet to a point, about 200 feet still higher, where the zone extends beneath alluvium. At the lower end, the zone terminates against a large body of granitic rock.

The zone strikes generally northward to north-northeastward and dips gently eastward. The best exposures are at the south end of the zone. These show a minimum thickness of at least 50 feet, but most of the contained rock appears to be subcommercial in grade and pale green to pale gray in color. Here, however, a layer of white silicate rock, rich in tremolite, overlies the diabase footwall. Where seen, this layer was about 8 feet thick. Its lateral extent was undetermined. An irregular body of silicated rock extends downward into the diabase from the main zone, but appears to contain little or no material of commercial interest.

The only underground workings consist of an exploratory adit driven in the early 1940's, from a point south of and about 100 feet below the southerly exposures of the zone. It extends for an estimated 420 feet N. 35° E. and thence 65 feet S. 60° E. It has penetrated mostly granitic rock and, for short distances, diabase, but does not intersect the talc-bearing zone. The remaining workings consist of several pits and trenches along the trace of the zone.

Arletta deposits. Generally referred to as "the Arletta deposits" are a group of talc bodies low on the east slope of the main ridge of the Ibex Hills and about 12 miles southwest of Shoshone, and 3½ miles north of the Monarch-Pleasanton mine. The bodies are covered by three claims all of which are owned by R. H. Morris and associates, 509 No. La Cienega Blvd., Los Angeles. The claims were located in 1937 and are in secs. 18 and 19, T. 20 N., R. 6 E. S.B.M. In the mid-1940's a small tonnage of commercial talc was shipped by the present owners, but only development work has been done since then. In mid-1961 the property was leased to the Southern California Minerals Company, 320 South Mission Road, Los Angeles.

The Arletta deposits are in the northern part of the fault block that contains the Monarch-Pleasanton deposit, described herein, and in essentially the same geologic setting (see general description of Ibex Hills). The talc bodies have formed along both margins of a diabase sill (fig. 13), which extends continuously and prominently northward from the Monarch-Pleasanton mine area. The sill, the talc bodies and the bordering strata, all of the Crystal Spring Formation, dip eastward, more steeply than the hill slope, so that the lower (quartzitic and shaly) units of the formation are topographically higher than the sill. Masses of the dolomite, that here composes the carbonate member, lie to the east of the sill where they form the lower slopes of the ridge.

The best exposed and apparently the largest of the bodies lies beneath the sill, dips about 70° southeastward, and is about 300 feet long. It terminates both to the northeast and southwest against cross faults. Where exposed in several shallow cuts and a drift adit, it appears to be 6 to 8 feet wide. It consists mostly of white laminated talc rock but which is generally tough and blocky. Bordering the footwall of the talc body is a several-foot thickness of limy and discolored alteration rock. The drift adit, which extends S. 30° W. from a point near the bottom of a small canyon, is about 50 feet long.

Other exposures of talc are distributed on both sides of the sill for several hundred feet north and south of the adit, and have been explored by cuts and shallow underground workings.

Atlas (Brown, Valley) deposits. All of the known exposures of talc in the Talc Hills are covered by a group of 11 contiguous claims that were first located in the 1930's by former State Senator Charles Brown. In 1944 the claims were purchased by the Western Talc Company, 1901 East Slauson Ave., Los Angeles. This company subsequently has applied the name "Atlas deposits" and engaged in exploration and development work, but by mid-1961 no talc had been shipped.

The claims extend northward for a distance of about 4 miles along the east face of the northern half of the hills. As indicated by the approximate county line, shown on the 1951 edition of the Shoshone quadrangle, the claims lie mostly in Inyo County, but the most southerly one extends into San Bernardino County. The claims are in sec. 21 and 28 (projected), T. 20 N., R. 5 E., S.B.M.

Most of the larger exposures of talc and most of the development work to date are confined to an area about one and one-eighth mile long at the southern end of the claims. In this area, as elsewhere, the principal talc bodies are underlain by a diabase sill that in turn overlies the characteristic quartzite and shaly members in the lower part of the Crystal Spring Formation. These bodies also lie along or near a major east-dipping low-angle fault that apparently everywhere has cut out the upper part of the Crystal Spring and in many places has caused rocks of younger formations (Beck Spring Dolomite, Kingston Peak Formation, Noonday Dolomite, and Johnnie Formation) to form the hanging walls of talc bodies. The presence of talc along the upper margin of the diabase sill seems to have offered a zone of weakness that localized the faulting.

Most of the exploration has been done at four localities, three within the above-mentioned southerly area and the fourth at the northern end of the group of claims. At the most southerly locality, white talc-bearing rock has been exposed, by trenching and bulldozing, laterally for about 500 feet. This body strikes N. 5° E., dips steeply eastward and is locally overturned. It is about 20 feet in maximum thickness, but pinches and swells markedly and probably averages no more than 8 feet thick. Its footwall is the upper margin of a diabase sill and is overlain by and in fault contact with conglomeratic quartzite of the Kingston Peak Formation and dolomite of the Noonday Dolomite. This bounding fault apparently cuts off the talc body at both ends. The body consists mostly of thoroughly crushed and sheared talc-rich rock, but a layer of laminated tremolite rock, two to three feet thick, is in contact with the diabase.

At another locality, about half a mile to the north of the most southerly prospect, lenticular bodies of talc occur along a fault contact between diabase of the Crystal Spring Formation and Beck Spring Dolomite. The fault strikes northward, dips moderately eastward and is a major rupture that can be traced for several miles. Although at the surface, it commonly is hidden beneath dolomite float, the existing exposures of the fault indicate that the talc bodies along it are discontinuous. The fault contact has been followed by a 150-foot (in mid-1961) drift adit that trends northward to northwestward from its portal low on the south slope of an east-trending ridge. Two bodies of commercial talc, 8 feet or more thick, were encountered, one in the first 30 feet of the drift and the other in the face. The bodies consist mostly of blocky material rich in the mineral talc and thoroughly crushed and sheared. The remainder of the drift is in highly brecciated waste-rock, mostly dolomite but also diabase and talc.

At the third locality, which is half a mile north of the drift, a north-striking zone of silication lies on the north side of an east-trending ridge. This zone is about 700 feet in exposed length and contains abundant talcose rock and tremolitic rock in an apparently continuous body 6 feet to 20 feet thick. The body is underlain by carbonate strata and green silicated rock and overlain by diabase. All of these units strike about N. 60° E. and dip gently to moderately eastward. Here, the east-dipping fault contact between the Crystal Spring Formation and the Beck Spring Dolomite, along which most of the nearby talc bodies occur, is separated from the silicated zone by the diabase body, so that the contained talcose and tremolitic rock is less fractured and sheared than that of any of the other talc bodies observed in the Talc Hills. It has been explored by means of several cuts and a 15-foot south-trending drift adit at the base of the ridge.

The fourth locality, at the northern end of the Talc Hills, and about 1¾ miles north of the last-mentioned deposit, contains a talc-bearing zone at the characteristic position above a diabase sill and at the base of the carbonate member, here massive dolomite, of the Crystal Spring Formation. Here, the zone and the bordering rock units strike northward and dip moderately eastward. The sill and the underlying sedimentary units of the formation, which ordinarily exceed 1000 feet in thickness, are here only a few tens of feet thick. The shortening has been caused by a major fault that separates the Crystal Spring strata from underlying older metamorphic rocks and by bedding plane faults within the Crystal Spring units. This faulting also has caused the talc bodies to be discontinuous and commonly crushed and sheared. In this area, exposures of silicated rock occur along a quarter of a mile segment of the contact between the diabase sill and the carbonate member. Within this segment, much of the contact is covered with talus, and, in some exposures, the contact shows little or no silication. The individual exposures are about 150 feet in maximum length. In them, the talc-bearing rock that is of possible commercial interest averages between 5 and 10 feet thick and is as much as 20 feet thick. Most of this rock is thinly laminated to blocky, but friable, foliated material is common.

Berryhill (Riggs) mine. The Berryhill mine is on the lower west face of the Silurian Hills. It is about 18 miles north of Baker and one-fourth mile south of the Annex mine. It is about one mile east of a former loading station on the now dismantled Tonopah and Tidewater Railroad. The deposit is covered by two claims in secs. 26 and 35 (projected), T. 17 N., R. 8 E., S.B.M. and owned by Harrison B. Gower (address: 4835 Forman Ave., North Hollywood, California) and A. L. Barton. The claims are leased to the Sierra Talc Company, 1608 Huntington Dr., South Pasadena, California. Local residents report that this is the property formerly referred to as the Riggs talc mine (Diller, 1914, pp. 157–160), which was one of the first operations in the Death Valley region. The Riggs mine was opened as early as 1911 or 1912, but was shut down in the early 1920's. It is said to have been worked briefly in the early 1940's but has been idle since then. Although the writer knows of no production records, the mine is estimated to have yielded no more than 3000 tons.

In the Berryhill mine area, the talc-bearing zone can be traced along-strike for several hundred feet (Kupfer, 1960). Here, the zone occurs along the upper margin of a diabase sill and is overlain by dolomite of the carbonate member of the Crystal Spring Formation. These units strike north-northeastward and dip moderately to gently eastward. Although the altered rock is 15 or more feet in average thickness, bodies of commercially valuable talc constitute only a small part of the zone. These bodies, which occur along the lower margin of the zone, are about 15 feet in maximum thickness and are about 150 feet in maximum observed length. Green silicated rock ordinarily forms the hanging wall and forms large masses within the bodies. The commercial talc ranges from well-foliated to blocky and from highly talcose to highly tremolitic.

The mined talc has been obtained from two bodies about 250 feet apart. One is exposed near the crest of a west-trending ridge; it has been penetrated by a 40-foot southeast-trending crosscut adit, followed by a 40-foot drift and stoped to the surface. The other, and more northerly body, is exposed near the bottom of a small canyon and has been worked through an interconnected group of short adits, winzes, and stopes. These have followed the body along-strike for about 150 feet and down-dip for about 50 feet.

Bonnie mine. The Bonnie mine, one of the more recently opened talc properties in the Death Valley region, is on the south side of lower Galena Canyon in the southeastern part of the Panamint Range. The mine property consists of 3 claims, side by side, in sec. 17, T. 22 N., R. 1 E., S.B.M., and owned by the Southern California Minerals Company, 320 South Mission Road, Los Angeles. The mine has been operated only in 1954 and 1955 when 2,300 tons of talc was mined.

The Bonnie talc deposit occurs along the lower margin of a septum of silicate-carbonate rock within diabase of the Crystal Spring Formation. The septum strikes northward, dips moderately eastward, and extends across a ridge which plunges northeastward beneath the alluvium in the floor of Galena Canyon. The septum is irregular in outline, but is at least 150 feet in maximum thickness. It is exposed laterally for about 800 feet. Its actual length is unknown, as both the southward and northward extensions of the septum are covered by alluvium.

The talc of commercial value occurs as layers and lenses of friable, white talc schist within the lower 40 to 50 feet of the septum. Green tremolitic rock composes the upper part of the septum and is also interlayered with the talc schist. The schist bodies are poorly exposed at the surface, but, where uncovered in bulldozer cuts, appear to be as much as 30 feet thick.

One body of talc schist has been followed underground and along-strike for about 400 feet westward from a point low on the west slope of the ridge. A drift-adit, about 320 feet long, is joined to two east-

Photo 7. View northward of part of Booth mine area. White cuts mark trace of principal talc body. Rough-weathering unit above body is carbonate member (cherty dolomite below and dolomite above) of Crystal Spring Formation. Smoother slopes below body are underlain by earlier Precambrian metamorphic rocks. Talc body marks approximate position of thrust fault which has cut out lower units of Crystal Spring Formation, has thoroughly crushed much of talc, and has caused body to be discontinuous. Entrance to original adit is at lower left. Entrance to later adit is out of view to right.

trending winzes; one about 85 feet long, driven from the heading of the adit, and another, about 40 feet and about 100 feet north of the heading. The two winzes are joined by a drift about 150 feet long and 30 feet down-dip from the adit level. Another drift extends for about 60 feet southwestward. All of the workings have been driven in the body of talc schist which dips 25° to 30° eastward and is at least 15 feet in maximum thickness.

Booth mine. The Booth mine, one of the earlier talc operations in the Death Valley region, lies at the easternmost tip of the Alexander Hills and about 11 miles east-southeast of Tecopa. The property consists of two claims, located in the early 1920's, and purchased soon afterward by Mr. Franklin Booth, then president of the Sierra Talc Company, now located at 1608 Huntington Dr., South Pasadena, California, which still owns the claims. The claims are in sec. 12 (projected), T. 19 N., R. 8 E. S.B.M. and were patented in 1951. Although its production records are incomplete the mine is estimated to have yielded about 12,000 tons of commercial talc, all mined by the present owner, and almost wholly in the period 1921–1935.

The Booth deposit is exposed, with an arcuate trace, on the south side of a low ridge that projects eastward from the Alexander Hills and is flanked on the north, east, and south by alluvium. In the mine area, the crest and north slope of the ridge is underlain by cherty dolomite and diabase of the Crystal Spring Formation. The talc bodies are discontinuously distributed along a fault contact between the dolomite and earlier Precambrian gneiss which is exposed on the south slope of the ridge. The fault, the talc bodies, and the overlying strata strike eastward, and dip moderately to gently northward (fig. 6). The fault is a major break which has cut out the quartzite, shale, and diabase bodies that persistently form the lower part of the formation in intact, nearby occurrences of the Crystal Spring Formation. The talcose layer at the base of the carbonate member has provided a zone of weakness along which the Crystal Spring units yielded.

The fault movement has caused the talc to be discontinuously distributed and to occur in bodies of irregular thickness. Much of the dolomite-gneiss contact is barren of talc, whereas, in some places, the talc bodies that separate the two units are 15 to 20 feet thick. On the surface, the talc-bearing zone can be traced for a lateral distance of about 1000 feet.

The size and distribution of the principal concentrations of talc cannot now be observed, as the underground workings are, in large part, inaccessible and the surface exposures are discontinuous. In general, the thickest and most extensive concentration is in the western part of the deposit where, at the surface, a 6- to 15-foot thickness of talc can be traced continuously for about 500 feet. This body has been mined down-dip for an average distance of about 180 feet, and ranges in thickness from a few inches to as much as 20 feet. Where mined it probably averaged about 8 feet thick. This body shows step-like rolls and is nearly horizontal in the intermediate and lower parts of the workings. The operators report that the talc was thickest in the steeper parts of the rolls. Some of the talc occurs as kidneys within the dolomite.

Although the wall rocks are thoroughly shattered, they show sharp contacts with the talc and are unmixed with it.

The Booth deposit has been worked from two levels, one about 70 feet higher than the other, and each with a separate entrance (fig. 6). The upper and first worked of the two, now largely caved, is appended to a north-trending adit driven from a point on the south side of the ridge. From this adit, a drift was driven, both east and west, for a total distance of several hundred feet. From the drift, which apparently follows the dolomite-gneiss fault contact, the talc bodies have been mined through irregular overhand stopes now marked by caved areas for as much as 225 feet northwest of the adit entrance.

The later and lower level extends westward from an opening at the east nose of the ridge and about 750 feet east-northeast of the entrance of the other adit. Although the western part of the lower level is now inaccessible, the operators report that the level is at least 500 feet long. These workings consist of a straight, west-trending adit, about 350 feet long, joined to a group of irregular drifts and exploratory tunnels. The adit intersects the talc-bearing zone at a point about 300 feet from the entrance. Thence, irregular workings branch southeastward to southwestward, mostly in the gneiss beneath the talc-bearing zone. The talc bodies have been tapped by numerous raises, many of which extend to the upper level. The downward extension of the zone, below and north of the lower level, remains unexplored. Although the operators report that, at the level of the lower workings, the talc bodies had pinched out or were too thin to be profitably mined, other bodies probably exist downdip and north of the workings.

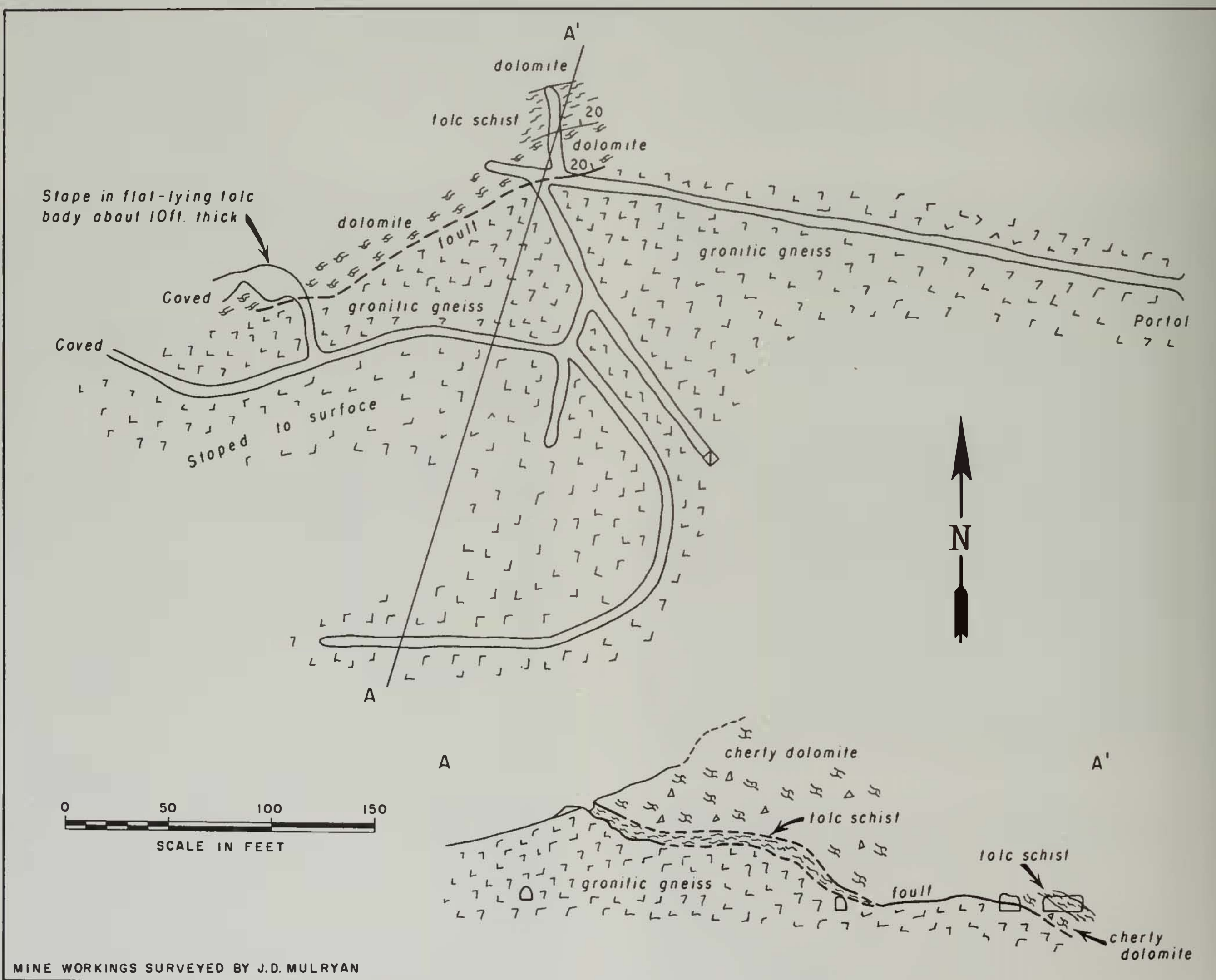

Figure 6. Geologic map of part of main level of Booth mine and cross section through Booth mine.

Caliente (B.F.J.) mine. The Caliente mine is on one of five claims located in the period 1952–54 by H. E. and E. T. Baumunk, 6521 Etiwanda Ave., Mira Loma, California, who began formal mining operations in 1954 and applied the name "B.F.J. mine." The claims are low on the west flank of the southern part of the Saddle Peak Hills. The claims are in sec. 32 (projected), T. 19 N., R. 6 E., and sec 5, T. 18 N., R. 6 E., S.B.M., and about 3½ miles due east of Saratoga Spring. The Baumunks and their associates operated the mine until late 1956, producing about 3200 tons of talc, when they leased the claims to the Sierra Talc Company, 1608 Huntington Dr., South Pasadena. Through 1959, the mine yielded an estimated additional 3700 tons.

The Caliente deposit occurs in a septum of silicated rock enclosed in a diabase sill. The septum is 25 to 50 feet in exposed width, strikes northward, and dips 10° to 30° eastward. It can be traced discontinuously for a distance of about 1200 feet around the nose of a west-plunging ridge, and extends beneath alluvium both to the north and south.

In the mine area, the commercial talc has been found in two bodies, one at or near the footwall and the other at the hanging wall of the septum. Both are 8 to 12 feet in average thickness and show an average dip of about 25° eastward. They are separated by 10 feet or more of limy, sub-commercial alteration rock. Both bodies consist of a blocky rock apparently composed of mixed talc, tremolite, and carbonate material.

The Caliente deposit has been mined through an inclined shaft which is about 280 feet long and slopes irregularly southeastward at an average angle of about 25°. Level workings have been driven northeastward at slope distances on the shaft of about 100 feet, 150 feet, and 230 feet and southwestward at slope distances of 150, 190 and 230 feet. The shaft has been sunk and most of the drifting has been done on the lower body. Above the 230-foot level, this body has been quite thoroughly stoped for distances of 50 to 60 feet southwest and 50 to 100 feet northeast of the shaft. The drifts extend no more than a few feet beyond the limits of the stopes.

Northeast of the shaft, the upper body has been penetrated by crosscuts from drifts on each of the three levels. Southwest of the shaft, it has been reached by a raise from the 190-foot level. A 140-foot drift on the 100-foot level constitutes the principal working in the upper body, and, in late 1961, this drift was being extended northeastward. Both bodies were found to terminate laterally against cross faults and to grade down-dip into carbonate-rich rock of less commercial value than the mined material.

A talc deposit known as the "Caliente Special" is exposed low on the north wall of a canyon about 1000 feet south of the main Caliente shaft. This deposit also is in a diabase-bordered septum that may be a southerly extension of the one that contains Caliente deposit, but bedrock in the intervening area is hidden beneath float. Here, the septum is about 30 feet thick and dips moderately eastward. It contains two layers of white alteration rock, containing mixed talc, tremolite, and carbonate and separated by a 10-foot thickness of green alteration rock. Its upper half consists of dolomite. The contacts within the septum are very irregular. The lower layer of white rock lies next to the diabase footwall and averages several feet in thickness. The upper layer pinches out downward in exposures on the canyon wall. A drift-adit, trending about N. 20° E. and following the lower layer, was begun in 1960 and was about 100 feet long in early 1961.

*Ceramic mine (including Patricia deposit)**. A group of shallow mine workings and exploratory excavations, generally referred to as the Ceramic mine, are distributed low on the west side of Silurian Peak in the southeastern part of the Silurian Hills. These workings are on three contiguous claims, end to end, in sec. 4, T. 16 N., R. 9 E., S.B.M.

The claims are owned by Harrison P. Gower (address: 4835 Foreman Ave., North Hollywood, California) and A. L. Barton. Formal mining activities on these claims appears to have been limited to the period 1940-42 when no more than 1000 tons was removed by a former owner.

In this area, units of the Crystal Spring Formation form a north-trending belt and rest upon earlier Precambrian metamorphic rocks. The Crystal Spring units consist of massive quartzite interbedded with layers of dolomite and limestone and containing irregular bodies of diabase and Mesozoic (?) granitic rock.

The layered units, in general, strike northward and dip moderately eastward, but are thoroughly broken by cross faults and bedding-plane faults. The talc bodies are irregularly distributed along a 2000-foot belt and are alterations of the carbonate rocks. Most of them border the diabase bodies, but a few occur as septa within the diabase.

The most extensively exposed and apparently the largest talc-bearing zone in the mine area lies mostly along or near the upper (eastern) margin of a diabase body and beneath a layer of carbonate rock. This zone can be traced discontinuously along-strike for about 1400 feet. It ranges in observed thickness from a fraction of an inch to as much as 60 feet, but the only material mined to date has been obtained from a layer of white, talc-rich rock that lies just above the diabase. This layer also is discontinuous and, where mined is only 2 to 4 feet thick. It has been irregularly intruded by small bodies of granitic rock.

The Ceramic workings, in the north-central part of the zone, have yielded all of the production to date. These are confined to a 300-foot segment of the zone and extend down-dip for a maximum distance of about 50 feet. These workings include three adits. The highest and most southerly is a drift-adit which extends south-southeastward for 110 feet. The central adit, with a portal 75 feet north of and about 25 feet lower than the portal of the southern adit, extends about 60 feet eastward through diabase and into carbonate strata. The talc body was encountered within the diabase and followed southward by means of a 200-foot drift. In the southern part of the drift, as elsewhere, dolomite forms the hanging wall. The principal stope

* Most of the data in this description was kindly supplied by Dr. D. H. Kupfer, Department of Geology, Louisiana State University.

joins the two drifts. The northern adit is about 30 feet lower than the central adit and also is a short crosscut through diabase to the talc body. It is joined to a 75-foot drift (mostly north of the adit), along the talc body. The Patricia workings are about 800 feet south-southwest of the Ceramic workings, and consist of a 40-foot inclined shaft and several cuts. The talc bodies here are similar to those in the Ceramic area, but no talc has been mined.

Comet deposit. The Comet talc deposit, in the east-central part of the Ibex Hills, is about 3000 feet south-southwest of the upper workings of the Eclipse mine and about 800 feet higher. It is covered by two claims in secs. 12 and 13, T. 20 N., R. 5 E., S.B.M. which, in 1961, was then owned by the Kennedy Minerals Company, 2552 E. Olympic Blvd., Los Angeles. Although the deposit was located in 1913 or earlier, it remains accessible only on foot and has been prospected by a few shallow cuts.

The deposit is exposed high on the south slope and crest of an east-plunging ridge. Here, units of the Crystal Spring Formation strike eastward, dip gently northward and rest upon older metamorphic rocks. Although these units are in normal stratigraphic position with respect to one another, they are highly fractured and have been greatly reduced in thickness by faulting parallel with the bedding planes.

The deposit can be traced laterally for about 1000 feet. It is underlain by diabase and locally by quartzite. The talc is an alteration of dolomite, locally siliceous, which forms the hanging wall. The thoroughly altered rock is confined to a single layer, which, in most places, is thoroughly sheared and fractured and shows pronounced irregularities in thickness. In most exposures, it is about 5 feet in thickness and contains abundant waste rock. In some places, it pinches out altogether. The deposit strikes eastward and shows an average dip of about 25° northward. To the west, it lenses out along the fault contact between diabase and dolomite. To the east, it terminates, with fault contact against the older metamorphic rocks.

At the surface, most of the talc of commercial interest is exposed at two places, one at each end of the deposit. At the western end is a body of white soft, thinly laminated to crudely foliated talc which is about 300 feet in exposed length, shows a maximum thickness of about 20 feet and averages 5 to 10 feet in thickness. The body at the east end of the deposit, which contains talc of similar quality, is 200 to 300 feet in exposed length and also is 5 to 10 feet in average thickness.

Crystal Spring mine. The Crystal Spring mine has been explored intermittently and by several lessors, but has yielded only a few hundred tons of talc. The mine is in the northwestern part of the Kingston Range, and is low on the north wall of the lower part of Beck Spring Canyon. The property consists of 4 claims in sec. 25 (projected), T. 20 N., R. 9 E. S.B.M. These are owned by John Prato, 14816 Valley Blvd., Fontana. Early in 1961, the claims were leased to J. R. Ralph, 1211 So. Willow Ave., Glendale, and William McDaniel, 1149 Bradford Dr., Glendale. A flowing spring on the property marks the type locality of the Crystal Spring Formation and would provide ample water for a mining operation.

In the mine area, units of the Crystal Spring Formation underlie the lower part of the north wall of the canyon, where they strike west to west-northwest and dip moderately to steeply northward. A few hundred feet south of the mine workings, quartzite of the lower part of the formation rests with fault contact upon older metamorphic rocks. Here, the quartzite is several hundred feet thinner than it is nearby; the missing strata apparently are cut out by the fault. A north-trending high-angle fault, the trace of which passes 250 feet south of the mine workings, has an apparent horizontal offset of about 4500 feet, cuts off the talc deposit, and brings Beck Spring Dolomite into contact with the Crystal Spring units.

The talc mineralization can be traced discontinuously eastward from the north-trending fault for a distance of about 2000 feet. The talc occurs in several bodies that lie near the base of a unit of siliceous dolomite. This dolomite, which here represents the carbonate member of the formation, is successively underlain by a 50-foot thickness of dolomitic quartzite. The quartzite forms the footwall of the western part of the talc deposit and is underlain by a diabase sill.

The widest and most continuously exposed segment of the deposit is at the western end and has been the most extensively explored underground. It can be traced laterally on the surface for about 200 feet. It extends beneath alluvium to the west and eastward to a north-trending cross fault of 20 or 30 feet apparent horizontal displacement. This segment strikes westward and dips about 60° northward. Within it, soft, foliated talc, apparently of commercial grade, ranges from a few inches to 20 or more feet in thickness. East of the cross fault, talc exposures can be traced along the same general trend for an additional 200 feet and appear to taper eastward. The talc is 15 feet thick near the fault.

The principal mine workings are confined to the westerly segment of the deposit. They consist of two east-trending drift-adits, one about 40 feet higher than the other, and a vertical shaft. The lower adit is about 175 feet long and has been driven along a part of the talc-bearing in thickness and, in general, is rich in carbonate material. The portal of the upper adit is about 70 feet east of the portal of the lower adit and leads to a 110-foot drift. Here, the talc body is 4 to 8 feet or more thick and consists of well foliated talc rock. The shaft is about 60 feet east of and 40 feet higher than the upper portal. It is 30 to 40 feet deep. Here, the talc body is about 20 feet thick. The bottom of the shaft is very close to the face of the upper adit, but the two workings do not join. Several small cuts compose the other workings.

Death Valley mine, including Mammoth workings and Sidewinder claims. Collectively grouped here under the name "Death Valley mine" are the mine workings and prospecting excavations that are covered by 24 claims in Galena Canyon in the southeastern part of the Panamint Range. The claims are largely or wholly within sections 7 and 18, T. 22 N., R. 1 E.

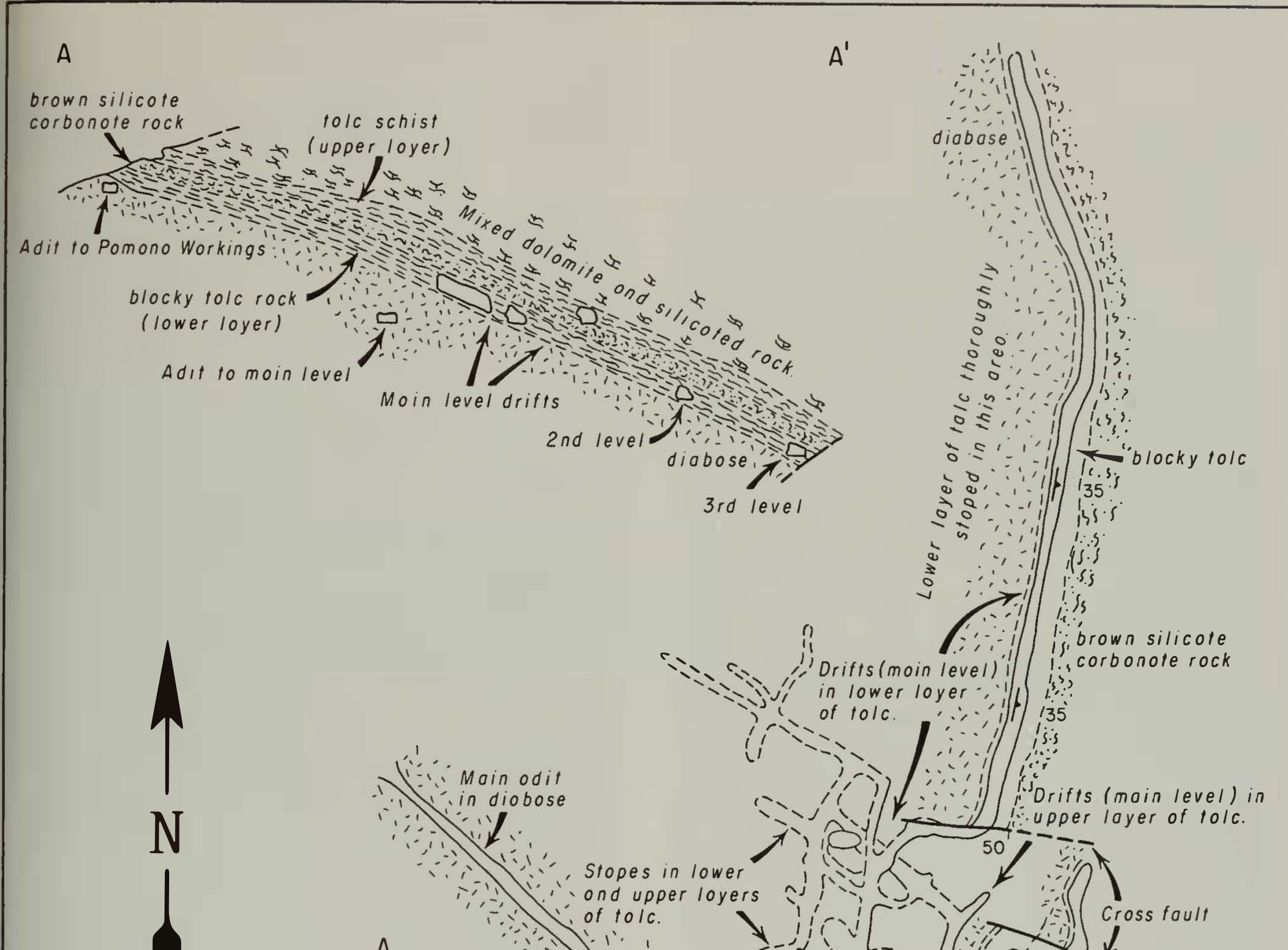

Figure 7. Map of main underground workings of Death Valley mine, showing selected geologic features, and cross section through main workings.

S.B.M., and secs. 19 and 20 (projected), T. 22 S., R. 47 E., M.D.M. They are owned by Kennedy Minerals Company, 2552 East Olympic Boulevard, Los Angeles.

In the late 1920's the Italian American Talc Company, S. W. Pepin, president, undertook the first mining of talc in the Galena Canyon area. At the site of the present Death Valley mine, at least a few hundred tons was mined in 1928 and 1929. This company became defunct, and several years of idleness followed. In 1937, the mine was reopened by the Death Valley Talc Company, of which Mr. Pepin also was president. During the period 1937–42, about 7,500 tons of talc was produced, first by this company and in 1940–42 when the property was under lease to the Pomona Tile Company. It was again idle until 1953, when the eleven claims that then constituted the property were sold to the Kennedy Minerals Company. Since then, it has been in nearly continuous operation and, through 1959, yielded an additional 55,500 tons of commercial talc. In recent years, the company has located and purchased more claims, bringing the total to 24. Mining during the early period was hindered by the remoteness of the mine and the capacity of nearer deposits to fulfill the demand for commercial talc in California. Consequently, the first operators sought the highest quality material. This was mined intermittently, hand-sorted, and sold mainly as cosmetic talc.

Most of the talc exposed in the Death Valley mine area is contained in three adjacent, north-trending fault-bounded blocks on the south side of Galena Canyon. Each block consists mostly of the typical sedimentary units and diabase of the Crystal Spring Formation. The talc bodies are at the characteristic stratigraphic position near the base of the carbonate member. The eastern and middle blocks dip eastward, whereas the western block contains a broad north-trending anticline, the axis of which is followed by the south branch of the canyon. Consequently, the talc-bearing zone can be seen repeatedly several times along the south side of Galena Canyon. High on the canyon walls, the upper units of the Crystal Spring Formation are capped by Noonday Dolomite, much of which is coarsely brecciated and forms land-slid masses.

The main talc bodies in the eastern and middle blocks resemble, in composition and in cross section, the principal bodies in Warm Spring Canyon 4 miles to the south. In each of the two blocks, a zone of strong silication overlies a diabase sill and contains two layers of commercial talc, characteristically separated by a several-foot thickness of brown silicate-carbonate waste rock. The lower layer, which directly overlies the diabase, is ordinarily about 15 feet thick and consists of blocky talc-rich rock with local tremolitic masses. The upper layer is 6 to 15 feet thick and composed mostly of strongly foliated and friable talc-rich rock. Some of the talc in the upper layer is blocky.

The middle fault block contains two talc-bearing bodies which are separated by a cross-cutting bulge in the upper margin of the sill and by minor cross-faults. The northern body shows the characteristic layering described above. It is about 1300 feet in exposed length, strikes about N. 15° E., and dips about 35° eastward. It terminates against diabase to the south and to the north. Down-dip, it probably extends to the north-trending fault which bounds the block on the east. This fault appears to dip steeply westward. The southern body in the middle fault block is about 700 feet in exposed length and remained nearly unexplored in 1960. It has altered from strata several tens of feet above the base of the carbonate member and appears to consist largely of sub-commercial material.

The middle fault block has been broken by cross faults, most of which strike nearly eastward. These have caused the zone to be offset for apparent horizontal distances ranging from a few feet to 60 feet or more, with the south sides moved relatively eastward.

The northern segment of the talc-bearing zone in the middle fault block yielded virtually all of the commercial talc mined on the Death Valley property prior to 1960 and contains the workings ordinarily referred to as "the Death Valley mine" (fig. 7). These workings, in mid-1960, have followed the body down-dip a maximum slope-distance of 500 feet from the surface exposures and along-strike for about 1000 feet.

The highest and earliest of the workings, known as the "Pomona workings" (fig. 7), consist mostly of an inclined shaft, 250 feet long, driven southeastward in the upper layer of talc. A drift, 125 feet from the collar of the shaft, extends about 100 feet northeastward and about 60 feet southwestward. The shaft is intersected by an adit about 150 feet long, also trending southeastward and extending through the upper part of the diabase sill and the lower layer of talc.

The main level of the principal workings consists of drifts, in both layers, connected to a southeast-trending adit driven about 400 feet through diabase. Parallel drifts extend to a major cross-fault, about 200 feet north of the point of penetration of the body by this adit. Similarly oriented drifts, also extending to the cross-fault, form most of the second level which is connected to the first by means of a 110-foot winze.

North of the cross-fault, the first level has been extended northward for about 600 feet by means of a single drift in the lower layer. Above this drift much of the talc in the lower layer has been stoped, but the second layer remains unmined. Both layers are virtually unmined below the first level and north of the cross-fault.

A third level lies 90 feet down-dip from the second level and consists of a drift that extends southward in the lower layer for about 120 feet from the bottom of the above-mentioned winze. Along the east wall of part of this drift, talc of the lower layer is in fault contact with diabase. This fault trends north-northeastward, dips moderately westward and appears to be parallel with and close to the downward projection of the major fault that bounds the block. The other two levels also were terminated southward within 150 feet of the winze when numerous cross-faults were encountered in this part of the zone.

On the eastern fault block, the talc-bearing zone is exposed laterally for about 2200 feet. Here, too, it strikes about N. 15° E. and dips about 35° eastward. For much of the length of this segment, the two layers of commercial talc appear to have joined to form a single layer 10 to 30 feet thick. Elsewhere in the segment, especially in the southern part, the characteristic layer of brown silicate-carbonate rock divides the layers of commercial talc. This segment is cut by numerous cross-faults with apparent horizontal displacements of a few feet to a few tens of feet. The block on the south side of each fault has moved relatively westward. This segment of the zone is fault-terminated north and south. The talc bodies in the eastern fault block were first explored underground in the late 1950's but remained unmined until late in 1960. They have been penetrated by a south-trending drift-adit which, in early 1961, was about 200 feet long. This and a shorter drift, lower on the same bodies, are known as the Mammoth workings.

A group of apparently small talc bodies called the Mongolian deposits, is exposed near the eastern margin of the eastern fault block. These lie on a near dip-slope of a dolomite body which strikes northwestward and dips about 45° to the southeast. The bodies are partly obscured by talus. A single cut has exposed one body, about 10 feet thick, composed mostly of talc schist.

The western block is about a mile and a half long, three quarters of a mile wide and fault-bounded on each side (pl. 1). Within it the Crystal Spring Formation is folded into a broad north-trending anticline, the axis of which approximately coincides with the floor of the southwestern fork of Galena Canyon. On both limbs of the anticline, the diabase sill has been intruded about 50 feet above the base of the carbonate member and is bordered top and bottom by zones of silicated rock, generally 100 to 200 feet wide. These zones, known as the Sidewinder deposits, dip moderately to gently into the canyon walls. They consist mostly of pale green tremolitic (?) rock which the operator considers to be noncommercial at present. Along the outer margins of these zones, discontinuous bodies of talc schist are interlayered with rock composed mostly of carbonate. Although poorly exposed and explored, these bodies appear to be rarely more than 6 feet in average width and more than 100 or 200 feet long. Several cuts low on the east wall of the canyon, however, appear to be on a single body of talc schist 400 to 500 feet long and 5 to 8 feet wide.

Most of the rocks on the north wall of the canyon consist of units that are stratigraphically higher than the talc-bearing zone. Near the mouth of the canyon and low on the north wall, however, is a poorly exposed body of silicated rock, the footwall of which extends westward and upward beneath a body of diabase which is flanked on the south, east, and west by alluvium. This body is exposed along-strike for about 200 feet. The footwall and the layering within the silicated body strike northward and dip gently eastward. A layer of commercial-grade talc schist, apparently 10 feet or more thick, lies above the footwall and extends beneath alluvium at both ends of the exposure. Two layers of talc schist occur higher in the body. One is three to four feet thick; the other is six feet or more thick.

Donna Loy mine. The Donna Loy mine is covered by a single claim at the southern end of the Nopah Range and about 8 miles east-southeast of Tecopa. The claim, which is in sec. 26, T. 20 N., R. 8 E., S.B.M., was located in 1944 by Fred R. Paulsen, George Cowsert and L. D. Fairbanks (address: Box F, Daggett), who retain ownership in 1961. The mine has been worked and explored intermittently since the mid-1940's and has yielded several tens of tons of commercial talc.

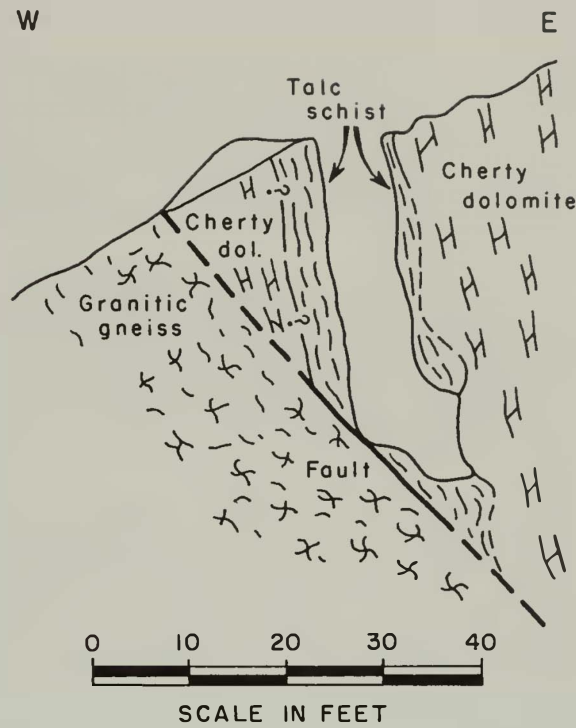

Figure 8. Geologic cross section through Donna Loy deposit.

In the mine area, cherty dolomite of the carbonate member of the Crystal Spring Formation rests with fault contact upon earlier Precambrian gneiss. The strata and the contact strike about N. 25° W. and dip steeply to moderately eastward. Missing here, and apparently faulted out, are quartzite, shale and diabase, which form the lower 1400 feet of the same formation in the Alexander Hills two miles to the southwest. Talcose rock, which has altered from the dolomite, is discontinuously exposed for a distance of about 1000 feet along or near the fault. As this deposit is in the same stratigraphic position as that at the Western mine in the Alexander Hills, it probably once occurred in the same geologic setting—along the upper margin of a diabase sill—but has provided a zone of weakness to localize the rupture. Consequently the talcose bodies within the zone are discontinuous, and, in most exposures, the talc is thoroughly sheared. Most of the talc is thoroughly fractured and friable and, in most of the exposures, appears to contain abundant carbonate material.

The zone, although generally obscured by a thin cover of dolomite float, has been exposed in several shallow cuts, a shaft and an adit, all within a lateral distance of about 1000 feet. In most of these exposures, the talc-rich rock is underlain by the gneiss and overlain by partly altered dolomite. Such exposures appear to represent discontinuous and faulted remnants of a once-continuous talc body. Others show talc mineralization in a layer or layers separated from the gneiss by 15 to 20 feet of less intensively altered dolomite.

The shaft, 36 feet deep and inclined 80° northeastward, has been sunk slightly south of the mid-point of the line of shallow workings and on a talc occurrence that is particularly thick and of commercial grade. At the collar of the shaft, the talc appears to be about 15 feet thick, but, in the bottom, the body has been nearly cut off by the gneiss along a fault plane that dips about 40° eastward. From the bottom of the shaft, the talc body has been followed 22 feet eastward along a drift in the face of which the talc is about 6 feet thick.

From its portal, about 200 feet south-southeast of the shaft, the adit has been driven northeastward and northward for a total distance of about 55 feet entirely within dolomite silicated to various degrees. A 6-foot layer of talcose rock is exposed near the portal; in the other cuts, the exposures of talcose rock are as much as 10 feet thick, but most contain abundant carbonate material.

Eclipse mine. The talc deposits in the Eclipse mine area are covered by three patented claims in secs. 7 and 18 (projected), T. 20 N., R. 6 E., S.B.M. which are in the north-central part of the Ibex Hills, Inyo County, and about 11 miles southwest of Shoshone. The claims are owned and the mine is operated by Kennedy Minerals Company, 2552 East Olympic Boulevard, Los Angeles.

This mine, one of the first talc operations in the Death Valley region, probably was worked as early as 1910. The records of the California Division of Mines show that, in the period 1910–18, a mine near Zabriskie siding on the Tonopah and Tidewater Railroad yielded about 1700 tons of commercial talc. This operation, quite certainly at the site of the present Eclipse mine, was successively under the control of the Quartz Crystal Glass and Manufacturing Company, the Pacific Mineral Products Company, and the California Mineral Corporation. The mine then appears to have lain idle until the mid-1920's, when it was reopened by the Italian-American Talc Company who applied the name Eclipse and in the period 1927–30 produced about 2000 tons. Another period of idleness lasted until 1945, when the mine was leased from the then owner, Mr. A. E. Nicholls, by the Kennedy Minerals Company. The property was purchased by this company in 1955. Since 1945, it has been in nearly continuous operation; by 1959, the output, including the early production, totalled about 45,000 tons of commercial talc.

The talc deposit, penetrated by the Eclipse mine workings, is contained in a fault-bounded block which in plan is shaped as a crude oval 2700 feet long, and 1800 feet wide, the long dimension trending west-southwest. The block underlies a spur which plunges northeastward beneath alluvium. The faults that bound the block are steeply dipping and probably join beneath the overlapping alluvium. The block is part of a terrane that has been identified with a highly faulted structural unit, exposed in the Virgin Spring area of the Black Mountains, which Noble has named the Virgin Spring Chaos (Noble, 1941; and Noble and Wright, 1954).

The block that contains the Eclipse mine consists only of units of the Crystal Spring Formation. In general, these strike northwestward and dip 30° to 50° northeastward. The talc occurs as a single tabular layer between a footwall of diabase and a hanging wall of dolomite. It is exposed from a point high on the slope of the spur northeastward and downward to a point near the bottom of the bordering ravine—a horizontal distance of about 1700 feet and a vertical distance of about 400 feet. Underground workings have penetrated the layer along-strike for a maximum distance of about 400 feet, but the maximum strike length of the body, which would probably be encountered in the lower part of the block, may well be as much as 1200 feet.

Although irregular in detail, the talc body, over-all strikes about N. 20° W. and dips 30° to 40° to the northeast. It ranges in observed thickness from 2 feet to as much as 30 feet, and probably averages about 15 feet thick. Like many of the other talc bodies in Death Valley region, that at the Eclipse mine contains a thinly laminated, blocky lower part and a schistose, friable upper part. The material in both layers of the Eclipse consists predominantly of the mineral talc. The operators report that the laminated layer, except where disturbed by faulting, is persistently about 3½ feet thick. Most of the pinching and swelling occurs in the schistose layer and is attributable to movement within it. Cross faults of small displacement cause steeply-plunging "ridges" and "valleys" in the footwall, and these are overlain by correspondingly thin and thick parts of the talc layer. Also common are broad undulations with axes parallel with the strike of the layer. Both layers are white and show little discoloration, although pale gray veinlets of carbonate are abundant through much of the body.

The Eclipse deposit has been penetrated by two groups of workings, one in the upper part of the block and the other in the lower part. The two (in mid-1961) were within 250 feet (slope-distance) of joining. The lower workings were the first to be opened and are the site of the most recent underground activity. The lower and longest level of the lower group is entered by means of a 200-foot southwest-trending adit driven through highly brecciated chert and dolomite, across the major east-trending fault that bounds the talc-bearing block on the north, and into the talc layer at a point several tens of feet beneath the lowest surface exposures of the layer (fig. 9). From here, a drift extends about 160 feet southeastward along the diabase-talc contact which, in several places, is offset by east- to northeast-trending faults, so that the south and southeast sides have moved relatively eastward and northeastward. Above this part of the main level, for a slope-distance of at least 150 feet, the talc has been extensively stoped to supply the early production of the mine. Some of the stopes are joined to a second level about 30 feet higher than the main level. The second level and the stopes are largely caved. In these workings, the talc layer seems to have been 8 to 12 feet thick.

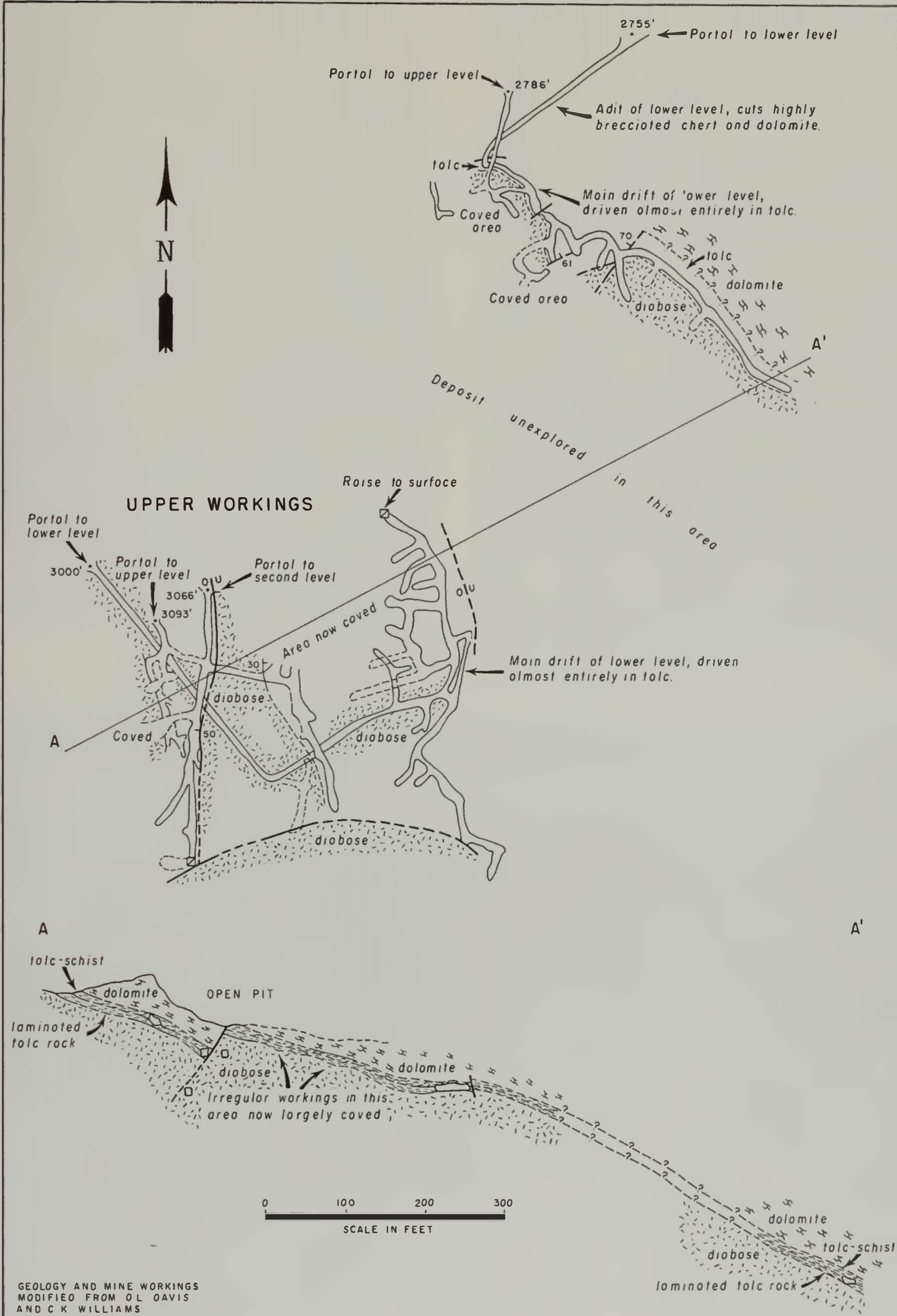

Figure 9. Map and cross section of underground workings of Eclipse mine, showing selected geologic features.

The early work in this part of the mine was halted when one of the northeast-trending faults was encountered, and the talc layer apparently was assumed to terminate against the diabase. In 1959 the lower workings were reopened; an extension of the level showed that the talc layer had been offset only a few feet. In mid-1960, the talc layer had been followed southward beyond the fault for a distance of 200 feet where the layer dips about 40° and pinches and swells about irregularities in the diabase footwall. Much of the talc contains abundant carbonate material.

The upper workings are confined to a triangular area (fig. 9) bounded: (1) on the northwest, by the higher surface exposures of the talc body; (2) on the northeast, by a north-northwest trending fault along which the hanging wall dolomite has moved relatively down; and (3) on the south, by a west-trending fault along which the footwall diabase was moved relatively up.

The approximate dimensions, in plan, of the triangular area are 450 feet on the northwest, 400 feet on the northeast and 450 feet on the south. Within this area, the talc layer shows marked undulations, the axes of which are approximately parallel with the strike of the body. Some of the undulations are caused by north- to northwest-trending faults which have displaced the footwall. Others are marked by actual rolls in the footwall. Also, within this area, the talc layer is broken into two segments by a north-trending fault, which dips moderately westward. On the east side of the fault, the talc layer shows an apparent upward displacement of about 50 feet.

The part of the talc body that lies west of the north-trending fault dips about 20° eastward from its surface exposures and thence takes the form of a large anticlinal roll, with the east limb against the fault.

The segment to the east of the north-trending fault is much the larger and probably is essentially continuous down-dip to the lower workings (fig. 9).

South of the west-trending fault, which bounds the triangle on the south, is an unexplored area in which the talc body probably also occurs, but in a structurally higher position. As this fault appears to be only a few tens of feet from the major fault that bounds the entire block, the tonnage of mineable talc between them would seem to be correspondingly small.

The upper workings have three portals, the lowest of which is about 950 feet southwest of the main level of the lower workings, and about 245 feet higher. Of the two higher portals, one is 65 feet and the other is 93 feet above the lowest. Most of the talc mined from the upper workings has been obtained east of the north-trending fault (fig. 9) and hauled through the lowest portal. This adit extends 280 feet southeastward and thence 190 feet east-northeastward, all in diabase, to the talc body. From this point, a drift extended about 250 feet southeastward to the west-trending fault which bounds the talc-bearing area on the south and an equal distance northward to a point near the surface. Talc has been stoped up-dip from this drift for an average distance of about 100 feet. The drift and the stopes are now caved, leaving a considerable tonnage of talc between them and the north-trending fault (fig. 9).

Photo 8. View northeastward of Excelsior mine area. Hill slope is underlain mostly by east-dipping units of Crystal Spring Formation. Low along near slopes, rough-weathering quartzite, in the lower part of the formation, rests with highly discordant, depositional contact on earlier Precambrian metamorphic rocks. Dark, smooth-weathering belt above quartzite marks position of diabase sill which, in turn, is overlain by light-colored, talc-bearing zone of alteration. On high skyline is rough-weathering Noonday Dolomite which rests with angular unconformity on upper units of Crystal Spring Formation.

Excelsior mine. The Excelsior mine, which has been operated nearly continuously and on a modest scale since 1936, is in the northeastern part of the Kingston Range. The mine property, about one and three-fourths of a mile long, consists of 12 patented claims which lie end-to-end along the west face of a north-trending ridge. They cover most of the talc-bearing zone described in the general discussion of the eastern Kingston Range. The claims are in secs. 25 (projected) and 36, T. 20 N., R. 10 E., and secs. 30 and 31 (projected), T. 20 N., R. 11 E., S.B.M. They were located originally in 1932 by former State Senator Charles Brown of Shoshone and were purchased soon thereafter by the present owner, Southern California Minerals Company, 320 South Mission Road, Los Angeles. This company has been the sole operator, and in the period 1936–1959, had produced 47,000 tons of commercial talc from the deposit.

Prior to the mid-1950's, most of the mining was confined to workings at the southern end of the group of claims and generally referred to as the Excelsior workings. Included under the name "Excelsior mine" are two other groups of workings—the Pioneer and Apex—which were opened in 1951 and 1957 respectively at points successively farther north along the zone. In the late 1950's, the southerly workings were shut down, and, since then, mining has been confined to the Apex workings, which are the northernmost of the three.

The talc-bearing zone in the Excelsior mine area, as elsewhere, is an alteration of the basal strata of the carbonate member of the Crystal Spring Formation. In most places, unaltered dolomite forms the hanging wall. Locally the silication extends through the entire thickness of the pre-existing carbonate strata. The upper margin of a diabase sill forms the footwall of the deposit for most of its length. But for a lateral distance of about 2500 feet, at the southern end of the deposit, the altered rock is separated from the sill by a layer of fine-grained quartzite.

Although the zone is remarkably continuous, its composition and internal structure differs from place to place. It ranges in thickness from about 20 feet to as much as 200 feet and contains abundant material of no present commercial value. Common within the zone, however, are exploitable bodies of commercial talc ranging in length from 200 to 1000 feet or more and from 6 to 20 feet wide.

In the vicinity of the Excelsior workings, where quartzite forms the footwall at the alteration zone, the mineable material consists mostly of talc schist and lies adjacent to the quartzite. Where diabase forms the footwall of the zone, a layer of laminated tremolite rock characteristically overlies the diabase, and bodies of talc schist occur as lenses higher in the zone.

At the southern end of the zone, the above-mentioned layer of talc schist has been followed underground for at least 600 feet along-strike and about 300 feet maximum down-dip, and probably has a considerably greater extent in both directions. This part of the zone, however, has been offset by several north- to northeast-trending faults (pl. 1) that may hinder future mining operations. The operators re-

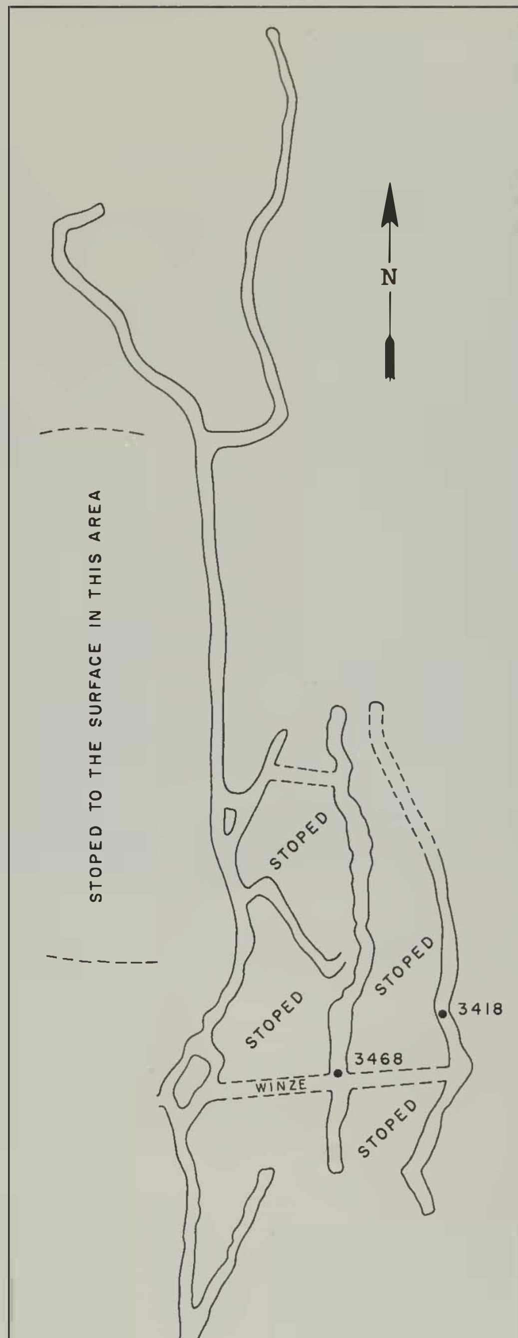

Figure 10. Map of main workings of Excelsior mine.

port that, where encountered, the talc schist layer was about 15 feet in average thickness and of good quality.

The main Excelsior underground workings, which center about this layer, were opened by means of a north-trending drift-adit, now about 750 feet long and partly caved. About 550 feet from the portal, the operators report, a cross-fault was intersected and two branches (fig. 10) of the adit were driven in search of the northerly extension of the talc schist layer. Although talc was encountered in both branches, that in the easterly branch, about 40 feet east of the main adit, appeared to represent the extension. Above the adit and south of the cross-fault, stopes extend to the surface. About 250 feet from the portal of the adit, a winze, inclined about 45° eastward, has been sunk for a slope distance of about 160 feet. Drifts have been driven from the 90-foot interval and from the bottom of the winze. The higher of the two extends about 50 feet southward and 180 feet northward; the lower one, about 70 feet southward and 280 feet northward. The winze and both of the lower levels lie within the talc schist layer and have not encountered the limits of the layer.

The Pioneer workings lie about 3000 feet north of the main working. Here, the diabase sill is overlain by a layer, 6 to 12 feet thick, of laminated tremolite rock. The underground work, however, was aimed at a down-dip intersection of a body of talc schist which, at the surface, occurs a few tens of feet above the diabase contact, is several feet wide and probably several hundred feet long. Here, the alteration zone and the enclosing units strike northward, dip 35° to 50° eastward and are cut by numerous northwest-trending cross-faults of small (several feet) displacement. The workings consist of a single adit, about 400 feet long, driven south-southeastward, at a small angle across the strike of the zone. It has penetrated silicated rock, most of which is of little commercial interest, and lies east of the layer of laminated tremolite rock which constitutes a mineable reserve of commercial talc. In 1960 and 1961 the Pioneer workings were operated intermittently and yielded modest tonnages of talc schist.

In the area of the Apex workings, about one mile north of the Pioneer workings, the alteration zone is at least 45 feet thick, and in general, dips 30° eastward. Here, the material of greatest commercial interest is highly tremolitic and occurs in a layer adjacent to the diabase footwall. The layer is 10 to 15 feet thick and of undetermined lateral extent. It is generally thinly laminated, but breaks into blocky fragments. In underground exposures, this layer is overlain successively by a 10-foot thickness of pale green limy waste rock, a 10-foot thickness of white talc-tremolite rock striped with veinlets of green serpentine, and another 10-foot thickness of varicolored limy, talc-rich waste rock. The talc-tremolite-serpentine rock may be of commercial value, but the layer remains unmined.

The Apex workings, in the tremolitic layer next to the diabase, consist of an irregular but generally south-trending drift-adit which, in late 1960, was about 300 feet long. Extending southward from a point near the adit entrance a parallel drift, about 110 feet long has been driven entirely in diabase. From about midway on this drift, an east-trending crosscut intersects the main drift and traverses the alteration zone. Most of the talc mined to date has been obtained from the drift adit, but this part of the zone remains incompletely explored.

Grantham (Warm Spring) mine. The Grantham mine, which in recent years has been the most productive talc operation in California, is on the east slope of the southernmost part of the Panamint Range. The 60 or more claims that compose the property are contiguous and lie in the lower (easterly) part of Warm Spring Canyon which drains eastward into southern Death Valley. The claims are owned by Miss Louise Grantham and associates, 1915 Pacific Coast Highway, Laguna Beach, California. The mine is operated by Grantham Mines of which Miss Grantham is owner.

The mine workings lie at elevations of 1800 to 2400 feet, and are distributed along a talc-bearing zone that is exposed at various points for a distance of two miles low along the south wall of the canyon and at several places on the north wall. Warm Spring, at the west end of the zone, also is owned by Grantham Mines, and provides water for the mining operation and the nearby mine camps.

The 11 original claims, which cover the most prominent exposures and now contain the principal workings, were located in the period 1931–35 by Miss Grantham and Mr. Ernest Hume. Seven of the claims lie end-to-end along the lower part of the south wall of the canyon. From east to west these are the Big Talc, Warm Spring No. 5, High-grade, Warm Spring and Warm Spring Numbers 2, 3, and 4. This group is bordered on the north by Warm Spring Numbers 6, 7, 8, and 9, which also lie end to end, and which cover the lower north wall of the canyon. The remaining claims were located in the 1950's. The mine has been in continuous operation since 1942 and through 1959 had yielded 310,000 tons of commercial talc to become the most productive talc mine in the western United States.

The lower part of Warm Spring Canyon is bordered mainly by metasedimentary rocks and diabase of the Crystal Spring Formation (see general description of talc in the southeastern Panamint Range, also p. 2). The basal strata of the Crystal Spring Formation are exposed on the canyon wall north of the mine camp and rest with depositional contact upon earlier Precambrian granitic gneiss and quartz mica schist. Along the south wall of the canyon the units of the Crystal Spring Formation are overlain by the Noonday Dolomite and by layered volcanic rocks mostly of andesitic composition and of Tertiary age. The volcanic rocks also are exposed high on the north wall of the canyon.

Like most of the larger talc bodies in the region, those in Warm Spring Canyon lie within a zone of especially strong alteration which is in the lower part

Photo 9. View southward of principal workings of Grantham (Warm Spring) mine; Big Talc portal on left middle and Number 5 portal on far right. Talc bodies occur in thick zone of silication that borders a diabase sill (dark exposures on lower slope) and has altered from lowest strata of carbonate member of Crystal Spring Formation. Unaltered dolomite and other sills of diabase form layered units on rest of slope.

of the carbonate member of the Crystal Spring Formation and adjacent to the lower sill of diabase.

In most of the mine area, the strata and diabase bodies of the Crystal Spring Formation strike northeastward and dip gently to moderately southeastward. Near the mouth of the canyon, however, these units are in a block at least two miles in diameter, which has been folded into a broad, east-plunging anticline. The block is bordered on the northwest by a northeast-trending fault which dips moderately northwestward (pl. 2B).

West of this fault the rocks of the Crystal Spring Formation are traversed by northwest-trending high-angle cross faults. The four most prominent of these show apparent horizontal displacements of 1000 to 2000 feet, and have, in general, cut the rocks into four slices 1000 feet to perhaps as much as 3000 feet wide. Although the faults apparently are normal, each segment of the talc-bearing zone has been offset relatively southeastward with respect to the segment that lies in the slice to the southwest. These major slices are cut by other northwest-trending faults of smaller displacement (fig. 11). The talc-bearing zone, therefore, has been broken into en echelon bodies, but the lengths of the individual bodies are generally obscured by a discontinuous cover of volcanic rocks and alluvium. Another major segment of the zone, and the one from which all but a small part of the talc production has been obtained, lies within the anticlinal block. The combined strike-length of the various segments of the talc-bearing zone that lie along the south wall of the canyon appears to be about one and one-half miles, but the extent of the mineable bodies of talc remains largely undetermined.

On the south canyon wall, the talc-bearing zone is exposed at five localities, each low on the slope and each on a separate fault-bounded slice which extends northeastward beneath the alluvium of the canyon floor. The zone also is exposed at several places on the north wall of the canyon, but the bodies of commercial talc there, appear to be either smaller or thinner than those to the south and remain essentially unmined.

The Big Talc and Number 5 claims were located along discontinuous exposures of talc on the gently-dipping south limb of the anticline near the mouth of the canyon. Here, the talc-bearing zone, when followed underground, proved to be remarkably uniform in thickness, composition, attitude and internal structure (fig. 11). At this locality the zone is about 60 feet thick and contains three talc-rich bodies which, in upward succession, are called by the operators the

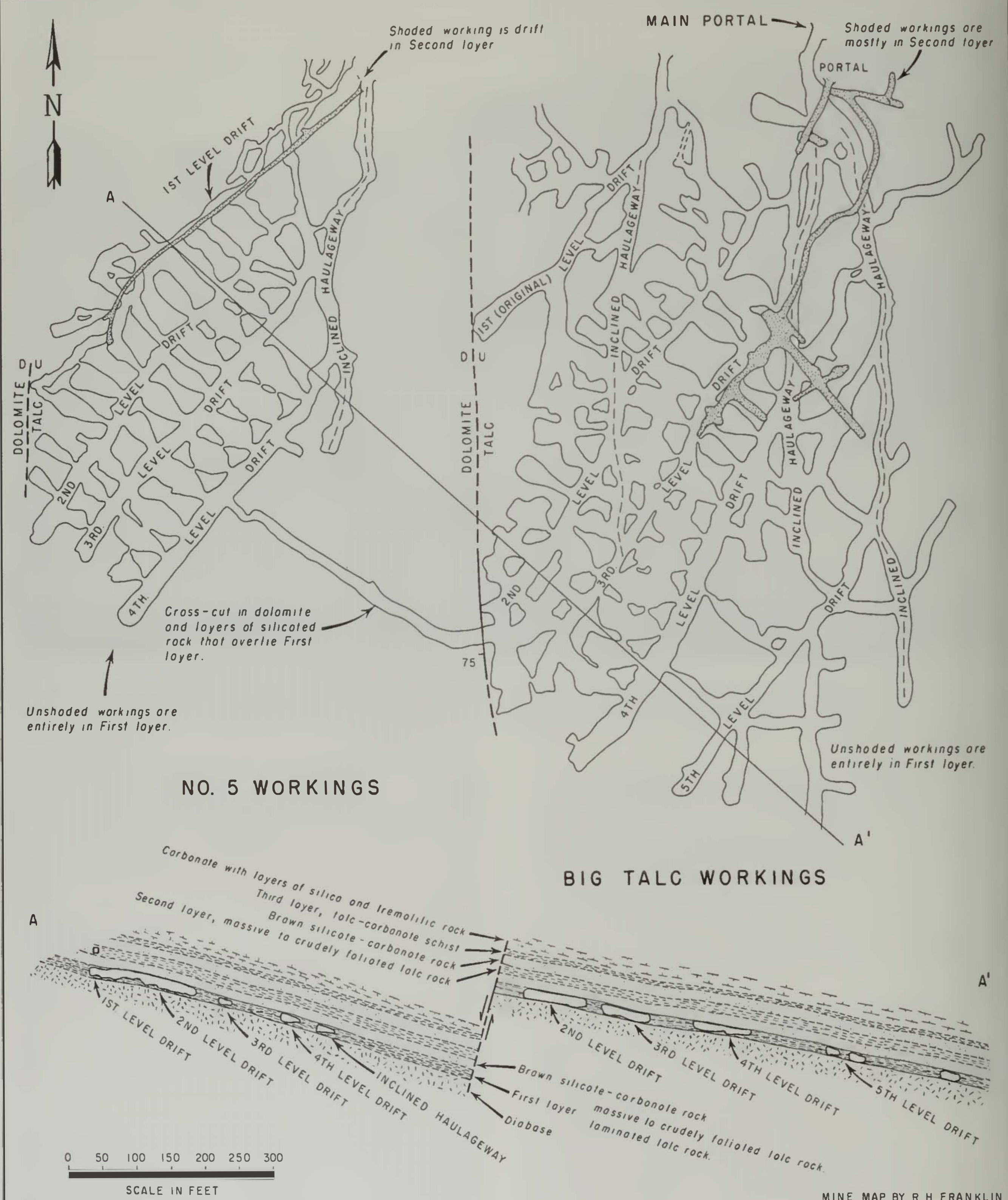

Figure 11. Map and geologic cross section of main workings of Grantham (Warm Spring) mine.

First, Second, and Third layers. The First layer is underlain by diabase of the lower sill, whereas brown, massive silicate-carbonate rock, of no present commercial value, separates the three layers.

All of the units strike northeastward and dip about 13° southeastward. This segment of the zone is cut by a steeply-dipping fault that trends northward, and along which the western side has moved relatively downward a distance of about 100 feet (fig. 11). The Big Talc and Number 5 workings lie east and west, respectively, of this fault.

The First layer, at this locality, has yielded all but a small part of the commercial talc produced at the Grantham mine, through 1960. It is nearly everywhere about 15 feet thick. In general, the lower half of the First layer is very thinly and evenly laminated, and the upper half is crudely banded and blocky. It is mostly white, but in some places it is tinted gray or pink.

Although the material in the First layer shows the above-noted gross textural differences, both the lower and upper parts seem to consist persistently of the mineral talc, subordinate carbonate material, chlorite and tremolite. The operators report that the entire body has shown uniform characteristics in commercial usage.

The Second layer, which lies about 15 feet above the First layer, is generally 12 to 13 feet thick, but only the lower 8 feet has been mined and marketed. This lower part consists of white, crudely banded, blocky, talc-rich rock which generally is softer than that in the First layer. The two are of comparable commercial value. The upper several feet of the Second layer consists of a talcose material that commonly shows a pale brown tint and remains unmined. Between the two parts of the layer is a persistent, red and orange ferruginous seam which has been avoided in mining.

The Second and Third layers are separated by an additional 15 feet of silicate-carbonate rock. The Third layer, although much less extensively explored than the other two, appears to be about 6 feet thick and to contain a higher proportion of carbonate material. The exploration of this body has been deterred by the greater size and greater ease of mining of the other two.

The aforementioned Big Talc and Number 5 workings (fig. 11), which lie one on each side of the north-striking fault, are the most extensive at the Grantham mine. In plan the workings are confined to an area about 1000 feet square. In each of the two, the First layer was mined originally by means of a drift-adit driven southwestward. As mining proceeded, winzes were sunk, and successively lower levels were opened at down-dip intervals of about 100 to 150 feet.

The Big Talc workings are the more extensive and include five parallel drifts 400 to 750 feet long. These trend S. 30° to 40° W. and are joined by winzes and stopes. The first three levels extend southwestward to the north-striking fault and are now largely caved. The fourth and fifth levels have not reached the fault. Down-dip from the fifth level, parallel winzes are being driven at intervals of about 90 feet in a modified room and pillar method of mining. The Big Talc workings have explored the First layer, from the surface exposures southward for about 1000 feet and from the north-trending fault eastward for about 500 feet. In these directions, the limits of the body have not been reached.

Phata 10. View of main portal of Big Talc workings at Grantham (Warm Spring) mine, showing removal of talc by diesel-powered truck. ***Photo courtesy Louise Grantham.***

In the Big Talc workings, as elsewhere, the Second layer has been much less extensively explored. It has been followed by means of a 500-foot drift, connected to a 200-foot winze, above the central part of the workings on the First layer, and tapped through connecting raises driven from the lower workings.

The Number 5 workings contain four parallel drifts in the First layer. These extend from the surface southwestward for about 750 feet and down-dip from the first level for about 300 feet. Between the lowest level and the north-trending fault is a triangular area, about 600 feet on a side, that contains an unexplored part of the talc-bearing zone. The first and second levels ter-

Photo 11. Underground view ot Gronthom (Warm Spring) mine showing diesel looder at face of lower layer af talc. ***Photo courtesy Louise Gronthom.***

minate southwestward against another north-trending fault. As dolomite is exposed in these headings, the talc-bearing zone probably has been down-dropped west of this fault. South of the workings, and between the two north-trending faults, the zone remains unexplored. In the Number 5 workings, the Second layer has been penetrated by a southwest-trending drift-adit about 530 feet long.

Formerly the Big Talc and Number 5 workings were mined by conventional methods in which the talc was loaded into mine cars by mucking machines and slushers and the cars hoisted up the winzes and trammed to the surface. Since 1955, diesel loaders and diesel trucks have been employed and the winzes have been relocated and driven so as to assure slopes of less than 10°. To accommodate the diesel equipment, a new and enlarged ventilating system was installed.

The Warm Spring workings are about 4000 feet west of the Big Talc-Number 5 area. Here, the talc-bearing zone strikes northeastward, dips about 25° southeastward and is exposed along-strike for about 750 feet. It extends northeastward beneath alluvium and may exceed 1000 feet in actual length. In internal structure, this occurrence closely resembles that in the Big Talc-Number 5 area and has yielded commercial talc from two layers. Here, the Second layer has been followed by means of a 40-foot gently inclined, south-trending shaft, joined to an 80-foot southwest-trending drift. At the end of the drift, the talc body terminates against a northwest-trending fault contact with dolomite. The First layer also has been worked underground, but less extensively.

On the Warm Spring Number 2 and Number 3 claims, are talc exposures which lie about 1700 and 3600 feet, respectively, west of the Warm Spring workings. Each is a few hundred feet long. The talc bodies represented by both exposures extend northeastward beneath alluvium, and the Number 2 body also extends southwestward beneath volcanic rocks. Exposed at each locality is a talc body that appears to be at least 20 feet thick, strikes northeastward and dips gently southeastward. Each resembles the First layer in the Big Talc-Number 5 area, but contains a few feet of tremolitic rock along the footwall and crumbly, foliated talc near the hanging wall. The talc exposures on both the Number 2 and Number 3 claims have been bulldozed. The body on the Number 3 claim has been followed southward by two inclined shafts about 50 feet apart, one 80 feet long and the other 50 feet.

The fifth major exposure of the talc-bearing zone, on the south side of Warm Spring Canyon, is on a segment known as the White Point or Number 4 deposit. It is the best exposed of the five principal occurrences of the zone and shows a 50-foot thickness of altered dolomite above the diabase sill. It strikes northeastward, dips moderately southwestward, and is exposed along-strike for about 1200 feet. This segment of the zone is broken by at least two northwest-trending cross-faults with displacements of a few tens of feet. Here, too, the talc of present commercial interest occurs in two bodies; one overlying the sill and another higher in the zone. Both are about 12 feet thick and are separated by a 10-foot layer of brown silicate-carbonate rock. The lower body consists mostly of thinly laminated to blocky rock rich in the mineral talc. Near the hanging wall are irregular masses of friable talc schist. The higher body contains talc-rich rock that, in general, is more friable than the lower layer.

The lower body of the White Point deposit has been followed by two shafts inclined 25° to 30° southeastward and about 900 feet apart. The more easterly of the two is 100 feet long; the other is 130 feet long and is joined at the bottom to a 35-foot, northeast-trending drift.

On the ridge that forms the north side of Warm Spring Canyon, the most continuous occurrence of the talc bearing zone is exposed high on both sides of the crest (pl. 2B). North of the crest it is at least three thousand feet in exposed length, but the contained talc bodies of commercial interest appear to be smaller than those to the south.

Ibex (Moorehouse) mine. The Ibex (Moorehouse) mine, one of the continuing sources of talc in the Death Valley region, lies in sec. 35 (projected), T. 20 N., R. 5 E., S.B.M. at the southern end of the Ibex Hills and about 3500 feet northwest of Ibex Spring. The property consists of 16 claims which were first located in the mid-1930's by John Moorehouse who opened the mine and worked it until 1941, producing about 1,100 tons of talc. Following a period of idleness, it was leased in the mid-1940's by the Sierra Talc Company, 1608 Huntington Dr., South Pasadena, the present operator. It is now owned by the C. O. Gould Estate, Frank Clapp, executor, Room 322, 4055 Wilshire Boulevard. Through 1959, the mine had yielded about 62,000 tons of commercial talc. Since 1957, the mine has been in operation briefly each year.

The Ibex deposit occurs within an arcuate slice of Precambrian rocks, which is bounded by two northwest-trending, high-angle faults. This sliver, convex to the northeast, is about 700 feet in average width and is 1¼ miles in exposed length. It lies along the southwest margin of the east-dipping fault block that forms most of the southern part of the Ibex Hills.

Although the rocks within the slice are highly fractured and faulted, and locally folded, they compose a crudely intact, southeast-dipping section in which, as in the bordering east-dipping fault block, earlier Precambrian metamorphic rocks are overlain by sedimentary rocks and diabase of the Crystal Spring Formation. Southwest of the fault that separates the slice from the block, these units have moved northwestward an apparent horizontal distance of 1400 feet. Thus, the Ibex deposit is an offset segment of the same zone that contains the Monarch-Pleasanton deposit, which lies on the opposite side of the fault.

The surface exposures of the Ibex deposit are distributed on both sides of a small, but precipitous canyon which drains southward from a divide on a southwest-trending ridge (fig. 12). This area is underlain mostly by various types of dolomite and limestone of

Photo 12. View northwestward of Ibex mine area, showing trace of main part of talc-bearing zone (white, upper right). Entire slope to left and right of zone is underlain by intricately faulted, sheared, and fractured units of the carbonate member of Crystal Spring Formation. Three lowest dumps mark levels of three main drift-adits. Dark exposures on lower left and in foreground are diabase.

the carbonate member of the Crystal Spring Formation. Less extensively exposed are irregular bodies of diabase and bodies of silicated carbonate rock. These units are so thoroughly faulted and sheared as to be chaotic in appearance. Most of the contacts shown on the accompanying map (fig. 12) are surfaces of movement. Within the contacts, the rocks also are abundantly sheared and faulted—so much so that the plotting of shears and faults was not practicable. The intricate disorder in the internal structure of the sliver is suggested by the irregularity in attitude of the carbonate strata, but the general attitudes and distribution of the sedimentary rocks in the immediate vicinity of the mine workings is that of a broad anticline which plunges moderately south-southeastward.

Most of the commercial talc in the Ibex mine area occurs in a discontinuous zone of white silicate-carbonate rock which is hook-shaped in plan, the long side trending southward from the crest of the ridge and diagonally downslope along the east wall of the canyon for a distance of about 600 feet. It thence curves across the canyon (around the nose of the anticline) and northwestward an additional 300 feet. At both ends, the body terminates in dolomite.

In detail, the outline of the zone is very irregular. In two places along the east limb, it pinches out altogether. Elsewhere, it is as much as 70 feet wide. The rock within the zone is highly contorted and sheared and the walls are poorly defined.

Numerous smaller bodies of talcose rock are irregularly distributed through the mine area. All are less than 100 feet in exposed length, and most are lenticular in plan. Although unsystematically oriented, they seem to lie along faults and to have provided the zones of weakness along which the rocks yielded.

The large body and most of the smaller ones are enclosed entirely in units of the carbonate member. The most common wall rock is a thinly layered, highly siliceous dolomite which occupies the central part of the anticline and appears to occur low in the carbonate member. This unit has been abundantly silicated not only to the white talcose material shown on the map but to green and gray tremolitic rock not shown. Around the nose of the anticline, platy limestone and massive dolomite and limestone lie along or near the hanging wall of the talcose body and apparently are stratigraphically higher than the siliceous dolomite. Some of the smaller bodies of talcose rock occur along

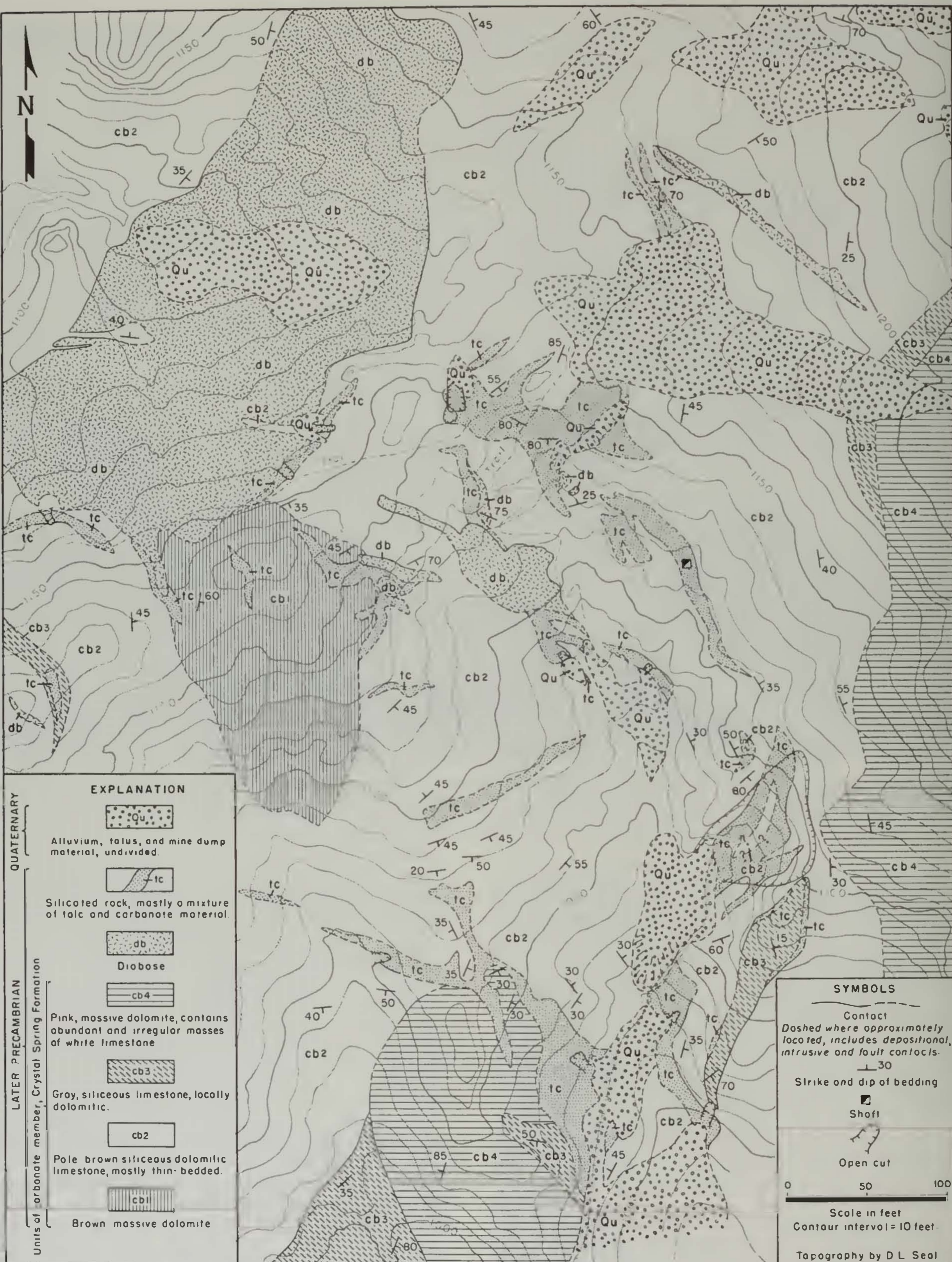

Figure 12. Geologic map of Ibex mine area.

the upper (southeastern) margin of a diabase sill that trends northeastward across the northwest corner of the mapped area.

Within the main zone, the white alteration rock grades from highly talcose schist to massive carbonate rock with little or no silicate fraction. Most of the mined material was obtained from a body of talc schist in the northern part of the eastern limb of the zone. According to the operators, this body was about 300 feet in maximum horizontal dimension, extended down-dip, from the highest surface exposures for a maximum distance of about 200 feet and averaged about 15 feet in thickness. Large tonnages of talcose rock with a higher carbonate content, but also of commercial interest, remain in the zone. The zone contains abundant waste material in the form of "lime boulders" (carbonate rock incompletely silicated) and greenish yellow alteration material.

The mine workings consist of three main drift-adits connected by numerous raises and extensive stopes (fig. 12). The adits, although irregular in detail and commonly branching, are generally north-trending. They have been driven from points near the canyon bottom at successively lower elevations. The vertical distances from the divide to the adit levels are about 90, 150, and 210 feet. From highest to lowest, they are about 315, 525, and 645 feet long respectively. Each follows the talc-bearing zone to the apparent termination of the zone along a line that plunges steeply northward from its most northerly exposures at the crest of the ridge. The body of talc schist that occurs in the western part of the zone has been extensively stoped, and much square-set timbering has been employed.

Jim Francis (Giant) mine. The Jim Francis mine, which has been one of the smaller and more short-lived talc operations in the Death Valley region, is near the base of the central part of the Ibex Hills. It is about 1½ miles south of the Eclipse mine, 12½ miles southwest of Shoshone, and in sec. 19, (projected), T. 20 N., R. 6 E., S.B.M. The one or more claims of the property are owned by Mrs. Mary Lou Walbergh, Palos Verdes Estates, California. The mine was worked only during the years 1942 and 1943 when, under lease to Mr. Harry Adams, it yielded 2000 to 3000 tons of talc (Harry Adams, personal communication, 1958).

The talc deposit at the Jim Francis mine is in an east-dipping fault block composed of units of the Crystal Spring Formation, and flanked by alluvium on the east and southeast (pl. 1B). Within this block, strata of siliceous dolomite of the carbonate member strike northward and dip about 60° eastward. Underlying the dolomite strata on the west is a diabase sill. Along the contact is a layer of greenish silicated rock, about 6 feet thick, which was considered waste rock in the mining operation.

All of the mine's output was obtained from a single lens that extends southeastward from a point near the greenish layer and dips about 55° northeastward. In plan, the lens is about 125 feet long and 25 feet wide and appears to pinch out downward within 70 feet of the surface. It appears to have consisted mostly of soft, highly foliated talc schist, in sharp contact with the dolomite walls, and also to have contained lenticular masses of dolomite.

The mine workings consist of two short, west-trending adits connected to a glory hole, the margins of which approximately coincide with the borders of the talc body. The lower adit is about 50 feet lower than the highest exposure of talc. The lowest exposures in the workings consist of partly altered dolomite and suggest that the alteration and perhaps concentrations of commercial talc extend to a greater depth.

Johnson (Kingston) deposit. The Johnson (Kingston) deposit, one of the more recently discovered and prospected talc-bearing localities in the Death Valley region is in the foothills of the southeastern part of the Kingston Range. The deposit is covered by a single claim of undetermined ownership but formerly owned by Richard W. Johnson, Shoshone, California. The claim is in secs. 25 and 26, (projected), T. 19 N., R. 10 E., S.B.M., and about 5 miles south-southwest of the Excelsior mine.

The deposit apparently is within the Crystal Spring Formation, but the members here resemble those to the north and west only in a general way. Here, a diabase sill, 50 feet or less thick, is underlain successively by the alteration zone, which constitutes the deposit, and strata of quartzite and shale (lower members?) of undetermined thickness. It is overlain by a layer of massive dolomite (carbonate member?) 20 to 50 feet thick. Still higher in the section, is a succession of thinly bedded quartzite, dolomite and shale (upper units?). In the vicinity of the Johnson deposit, the sill and the strata strike northwestward and dip moderately northeastward.

The zone of alteration is exposed on two north-trending ridges and can be traced laterally, from the crest of the more westerly ridge, southeastward diagonally across a small canyon to the crest of the other ridge—a total distance of about 1300 feet. The zone, although poorly exposed, shows marked differences in thickness and in the character of the material it contains. In most places it seems to be 10 to 15 feet thick, has a maximum thickness of 50 to 100 feet at the southeastern end of the exposures, and locally may pinch out altogether.

Although the altered rock has not been thoroughly tested as a commercial material, much of it appears to be of commercial interest. Some of it probably is rendered sub-commercial by a high carbonate content or discoloration. On the west wall of the canyon, white foliated talc about 10 feet thick has been uncovered. At its thick, southeastern end, the deposit consists mostly of white to pale green, highly tremolitic material intercalated with layers and lenses of carbonate-rich rock. As most of this part of the deposit forms nearly a dip-slope on the east side of the ridge, it would be easy to mine.

Kingston (Kingston No. 8) deposit. The Kingston deposit comprises a group of talc bodies at the head of Back Canyon (pl. 1B), which drains west-northwestward from the Kingston Range. These have been prospected but remain unproductive. They are covered by three claims, in secs. 4 and 5 (projected), T. 19 N., R. 10 E., S.B.M. which were located by the present owner, Harry Adams, Box 322, Bloomington, California. The bodies lie at the eastern end of the talc-bearing belt that is discontinuously exposed for a distance of 6 miles along the lower slopes of the canyon.

In the mine area, sedimentary rocks and the diabase sill of the lower part of the Crystal Spring Formation strike northwestward and dip steeply northeastward. Here, the quartzitic and shaly strata that underlie the sill are only 200 to 300 feet thick. The remaining several hundred feet of the lower strata apparently have been cut out along an intrusive contact with the large body of quartz monzonite which underlies the main mass of Kingston Peak to the south.

The exposures of talcose rock are confined to an area, about 600 feet square, just south of the drainage divide at the eastern end of the canyon. Although the exposures are poor, they show occurrences of talcose rock along the southern margin of the diabase sill, and, at two localities in the quartzite, on the hill slope above the sill. As at the Sam Flake and Vulcan deposits to the west, the diabase has been intruded above the lowest strata of the carbonate member. The strata of the carbonate member lie mostly above the sill and also have been altered, but less intensely than those beneath the sill.

The body of talcose altered rock along the lower margin of the sill can be traced laterally for several hundred feet and strikes northwestward. It has been cross-cut by a single adit about 50 feet long and trending west-southwestward. Here, the body is about 25 feet thick and dips steeply northeastward. It contains abundant, hard, limy material.

The bodies of altered rock exposed on the hill to the west seem to be lenses enclosed in quartzite and to represent partly silicated strata of carbonate rock. The largest lens uncovered to date is at least 150 feet long and about 25 feet in exposed width. It also strikes northwestward and dips steeply northeastward. This body consists of soft and white talc schist mixed with masses of limy rock. It is best exposed near the entrance of an adit which extends southwestward for about 60 feet, mostly through quartzite, and then 30 feet southward along another body of altered rock which strikes southward and also dips steeply southeastward. This body is about 15 feet in exposed thickness and consists mostly of limy talcose rock.

Mammoth mine. The Mammoth mine, which has been worked intermittently and on a small scale, is in the east-central part of the Ibex Hills and about 1½ miles south-southwest of the Eclipse mine. It is covered by a single claim in sec. 24 (projected) T. 20 N., R. 5 E., S.B.M.

The claim is owned by Tennessee Minerals, Inc., 5433 Reseda Blvd., Tarzana, California. Since the late 1940's when the mine was first worked, it has yielded four to five thousand tons of talc.

The mine is within the area of intricate faulting noted in the general description of the Ibex Hills (pl. 1B). The mining operations have centered about a large exposure of talcose rock on the lower part of a precipitous nose of a southeast-trending ridge. The deposit is part of a narrow, north-trending fault-block which is about 800 to 1000 feet in average width, at least one mile long, and which, at the surface, consists entirely of sedimentary rocks and diabase bodies of the Crystal Spring Formation. These, in general, dip gently to steeply eastward.

Exposed in upward succession, on the southeast face of the nose, are a diabase sill (at least 150 feet thick), a zone of alteration (30 to 40 feet thick), and cherty to massive dolomite (several hundred feet thick) which forms a nearly perpendicular face above the deposit. Although talc alteration occurs for a distance of at least 1000 feet along the upper margin of the sill, much of the contact is alluvium-covered. The mine workings seem to be on the largest single body of talc-bearing rock along this contact.

This body is about 250 feet in exposed length, strikes north-northeastward, dips about 20° eastward, and extends up-dip beneath the dolomite cliff. As this body forms nearly a dip slope, its full thickness is not well-exposed, but the 30- to 40-foot figure appears to be the maximum thickness of a bulge that thins in both directions from the principal exposure. To the north, the bulge terminates against an irregularity in the upper margins of the diabase sill. Its southern extension is partly obscured by alluvium in a small canyon, but, in discontinuous exposures beyond the alluvium, the zone of alteration is only a few feet thick.

The lower two-thirds of the bulge consists of thinly laminated rock which, in the higher part, is composed mostly of talc and, in the lower part, is highly tremolitic and locally colored pale green. The upper one-third consists of talc schist containing irregular masses of greenish gray waste rock.

The deposit has been worked by means of an open cut. With the depletion of the commercial talc on the dip-slope, operations must be extended underground.

Markley deposits. A group of talc bodies, generally referred to as the Markley deposits, lies high in the central part of the Ibex Hills. They are exposed at numerous places and are aligned in essentially the same zone which trends northward for a distance of about 2¼ miles near the crest of the hills. This zone is covered by 7 end-to-end claims located in 1942 by F. A. Markley and Walter Haney. They are in secs. 11, 12, and 13 (projected) T. 20 N., R. 5 E., S.B.M. In the mid-1940's they were acquired by the present owners, the Sierra Talc Co., 1608 Huntington Dr., South Pasadena, California. Although prospected at numerous places by means of shallow workings, the deposits remained unproductive in 1961.

In this part of the crest of the Ibex Hills, metamorphic rocks of earlier Precambrian age are successively overlain by nearly continuous and persistently east-dipping layers of quartzite, diabase, and dolomite of the Crystal Spring Formation. In all but the southern part of this talc-bearing zone, the Crystal Spring strata rest with fault contact upon the older rocks. Moreover, faulting parallel with the layering in the Crystal Spring units has cut out many of the strata and, in most places, has caused the units to be much thinner than the corresponding members in nearby, intact sections. Enclosing the southern segment of the zone is a nearly unbroken block, about half a mile long, of this part of the Crystal Spring Formation.

As elsewhere, the alteration to talc is confined almost wholly to the lower strata of dolomite, and diabase forms the footwall of most of the observed occurrences of the altered rock. The zone of alteration, however, also has been a zone of weakness along which much of the fault movement has occurred. Consequently, the talc-bearing bodies are highly fractured, sheared, and discontinuous. Talus from the overlying dolomite covers the diabase-dolomite contact, but where exposed, the zone of alteration is rarely more than a few feet thick. Much of the contact is barren of alteration rock or nearly so—apparently as a result of the faulting parallel with the contact. The contact also has been displaced by numerous cross-faults with offsets of a few feet to a few tens of feet. The abundance, thickness, and lateral extent of the commercially significant talc bodies within the zone, therefore, are incompletely known.

Probably the most continuous, thickest and most uniform body is in the relatively unbroken block at the southern end of the zone. This body is discontinuously exposed along the east side of a dolomite cliff and, in 1961, remained accessible only by foot, being about three-quarters of a mile south of the end of the access road to the Markley deposits.

Here, for a distance of 800 to 1500 feet, the diabase sill is overlain by a talc body that appears to be of commercial grade and of an economically mineable thickness. Where exposed, the body ranges in thickness from 6 to 12 or more feet and consists predominantly of white talc schist. Also common is a several-foot thickness of laminated tremolite rock next to the upper margin of the diabase sill. This body dips gently eastward, and much of it is covered by talus from the cliff. It has been prospected by means of several cuts, and remains unworked mainly because it is of difficult accessibility.

Most of the exploration has centered about a segment of the zone of alteration which is exposed just south of the end of the access road. Here, the altered rock, which also overlies the diabase body, can be traced laterally southward for about 800 feet. The material of commercial interest is very irregular, ranging in thickness from 2 to 10 or more feet and cut by numerous cross faults. It consists mostly of very white talc schist and laminated talc-rock. The zone has been explored underground by means of a drift-adit that extends southward for about 200 feet. This adit penetrated a body of talc schist near the portal and was then driven through crushed dolomite to encounter another occurrence of talc schist near the present face. This work is as yet too limited to reveal the extent of the mineable material.

For a distance of at least one mile north of these workings are numerous exposures of talc-bearing rock in the same geologic setting as those previously described. Most of these appear to be in bodies that range from a few tens of feet to a few hundred feet in length and from a foot or two to as much as 20 feet in width. They consist mostly of thoroughly sheared and fractured mixtures of talc schist and laminated talc rock. They have been explored by means of shallow cuts and remain poorly exposed.

Photo 13. Aerial view northwestward across southern end of Ibex Hills showing Monarch deposit and workings (right foreground), Pleasanton deposit and workings (center mid-distance). Main ridge is underlain by units of later Precambrian Crystal Spring Formation which dip steeply eastward. Dark band low on slope is diabase sill.

Monarch (Monarch-Pleasanton) mine. The property now known as the Monarch mine embraces two groups of workings—the Monarch and Pleasanton—which, in the 1940's, were operated as separate mines. In the period 1956–61, they became consolidated under a single owner and have since been operated as a single mine. The workings are about half a mile north of Ibex Spring at the southern end of the Ibex Hills, and are about 16 miles south-southwest of Shoshone. The property is covered by five claims which are owned by Ralph Morris and associates, 509 No. La Cienega Blvd., Los Angeles and are under lease to the Southern California Minerals Company, 320 South Mission Road, Los Angeles. The claims are in secs. 1 and 2 (projected), T. 19½ N., R. 5 E., S.B.M.

The original Monarch mine was first worked by Mr. Morris and his associates in 1938, and, in 1945, was leased to the Sierra Talc Company and operated until October 1950, when the lease was relinquished. During the period 1938–50, the mine yielded about 46,000 tons of commercial talc. It remained idle until 1956 when the claims were leased to the present operators, the Southern California Minerals Company.

The original Pleasanton mine was opened early in 1942 and, in the following October, was leased to the Muroc Clay Company. In 1946, the lease was acquired by the Sierra Talc Company which operated the mine until 1947, when the total production had reached about 16,000 tons. The mine remained idle until the late 1950's, when it was connected with an extension of the Monarch workings. The mine was acquired by the Southern California Minerals Company in 1958.

From 1956 through 1959, the production from the combined workings totaled about 7,500 tons, bringing the over-all production to 69,500 tons. Extensive development work also was done during this period. Nearly all of the commercial talc produced to date has been of the foliated talc-rich variety.

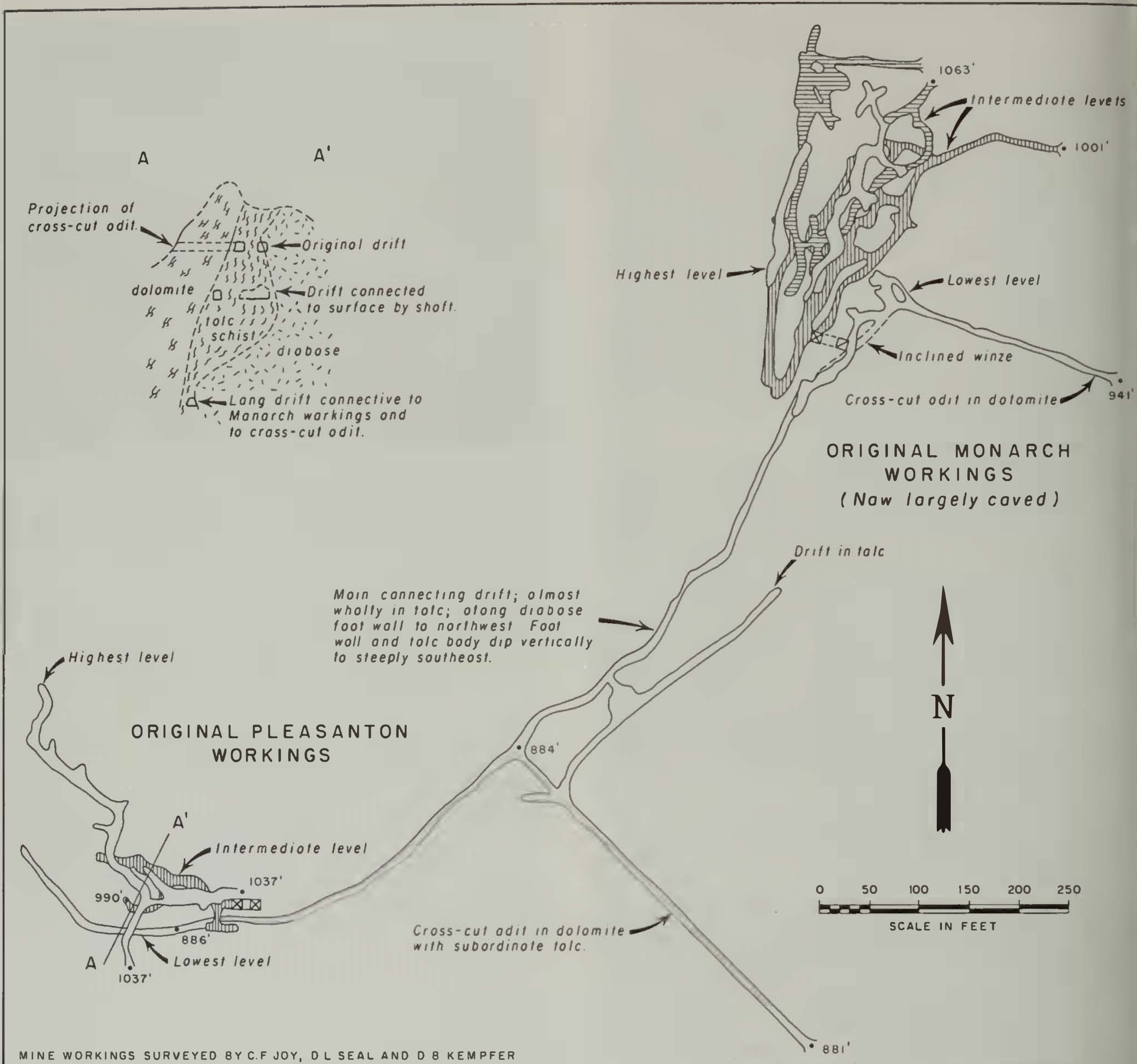

Figure 13. Map of Monarch-Pleasanton mine workings and cross section through Pleasanton workings.

In the area of the Monarch-Pleasanton workings, the crest and most of the east face of the Ibex Hills are underlain by sedimentary units and a diabase sill, all of the Crystal Spring Formation, and all dipping steeply eastward (fig. 13). On the west face of the hills, the basal Crystal Spring strata rest with depositional contact upon older metamorphic rocks, whereas a talc-bearing zone, which overlies the diabase sill, is exposed low on the east face. All of these layered rocks are cut off on the southwest by a northwest-trending fault, the southwest side of which has moved relatively northwestward.

The trace of the talc-bearing zone is in the form of a hook, about 1900 feet in total exposed length, open to the north, the long side trending northward. The short side points northwestward, apparently folded by drag along the northwest-trending fault. The zone is underlain by diabase, which forms the interior of the hook, and is overlain mostly by dolomite, irregularly shaped bodies of which rim the outside of the hook. Most of the dolomite is of the carbonate member of the Crystal Spring Formation, but, in one place, the zone is overlain, with fault contact, by a block of gray Beck Spring Dolomite.

Virtually all of the talc of commercial grade exposed at the surface occurs in two bulges, one at each end of the zone and about 900 feet apart. The bulge at the southwest end contains the Pleasanton workings, and the bulge at the northeast end contains the Monarch workings. Surface exposures between the two bulges show only a narrow and weak zone of silication, but underground exploration in 1956 and 1957 revealed that this part of the zone widens with depth and contains mineable widths of high-quality talc almost continuously between the Monarch and Pleasanton workings. This discovery demonstrated the desirability, in other areas of proved talc mineralization, of underground exploration along the talc-bearing zone, even though surface exposures of the zone are barren of mineable concentrations of talc.

At the Monarch workings the exposure of high-quality talc is crudely triangular in plan, about 400 feet in longest dimension (along the diabase footwall) 200 feet in maximum width, and tapering northward into the diabase sill. Underground work has shown that this taper is the surface expression of a south-plunging trough for which diabase forms both footwalls. Along the other leg of the triangle, dolomite forms the hanging wall and appears to consist mostly of the carbonate member of the Crystal Spring Formation. The hanging wall here, however, is closely paralleled by a major fault that brings Beck Spring Dolomite into contact with the carbonate member and may locally form the hanging wall of the talc. This bulge in the talc-bearing zone plunges moderately to the southeast, tapers downward, and averages 80 feet in thickness.

In the area of the Pleasanton working, the surface exposure of commercial-grade talc is about 60 feet in maximum width and 600 feet long. In this area, the body has been encountered at three levels underground, the lowest of which is 150 to 250 feet beneath the surface exposures (fig. 13). Everywhere the dolomite hanging wall dips 70° to 80° southwestward, but the diabase footwall shows marked undulations, causing the talc body to pinch and swell and to range in width from a few feet to as much as 80 feet. In the Pleasanton area the talc body thins markedly with depth (fig. 13), but this pinching does not necessarily indicate a downward termination of the body.

Although the continuity of the talc body has been proved between the two workings, its full thickness here is not everywhere known. For a lateral distance of about 300 feet, talc has been mined in drifts at distances of 60 to 150 feet from the diabase footwall. Abundant waste rock was encountered in these drifts, but it appears to be in the form of various-sized boulders surrounded by talc.

The Monarch-Pleasanton deposit throughout consists predominently of very white and friable talc schist. Massive tremolite rock forms local masses within the deposit and laminated tremolite rock commonly forms a layer one to two feet thick along the diabase footwall. Masses of sub-commercial alteration rock occur within the talc-bearing zone, but in most places they constitute a small fraction of the thickness of the zone. Small pods and stringers of galena have been occasionally encountered, but appear insignificant either as a possible source of lead or as a harmful impurity.

Photo 14. View southwestward of Pleasanton talc body, overlain by dolomite (dark ridge), and underlain by diabase (smooth slopes in foreground).

Talc in the Monarch area was mined first by means of an open cut and then through three levels (fig. 13) driven successively from the hill slope at vertical intervals of about 60 feet, and kept mostly within the southeast-plunging and downward-tapering bulge. The upper two levels, now largely caved, are exceedingly irregular and each penetrates the talc body laterally for about 250 feet and through a width of about 80 feet. The lowest level consists of a drift about 150 feet long. The upper level, since its completion, has been largely incorporated in the open pit. Between levels, the talc has been thoroughly stoped, and square set timbering has been extensively used. The previous operator estimates that about 70 percent of the talc above the lowest level has been removed.

In the area of the Pleasanton workings the talc body was first mined by means of an open cut and on three underground levels, the lowest of which is 150 feet to 250 feet lower than the surface exposures of the body. The first level consists of a drift adit driven about 300 feet irregularly northwestward from a portal near the lowest outcrop of the body. Appended to the adit are short cross-cuts and parallel drifts that show a talc width of 40 to 60 feet for most of the length of the workings.

Near the portal of the adit is a 45-foot shaft, steeply inclined westward, which connects with another drift (second level), this one extending northwestward about 150 feet from the bottom of the shaft. Here a 70-foot maximum width of talc is shown. From this level to the surface the talc has been extensively stoped.

A third level was established in the Pleasanton workings when the drift that connects them with the Monarch workings was driven about 100 feet beneath the second level and about 70 feet to the southwest and west of it. The two are connected by a raise.

Work on this newest level was begun in 1956 when a gently-inclined winze was driven 140 feet southwestward from the lowest level of the Monarch workings and thence was extended as a drift. This drift was later joined by an adit driven 400 feet northwestward from the hillside. Most of the talc removed from this property in the period 1958–61 has been obtained from this drift, shorter drifts that extend from the adit, and from stopes appended to the level workings.

Montgomery (Panamint) mine. The Montgomery mine, the most westerly of the talc operations in the Death Valley region, lies high on the ridge that separates Warm Spring and Galena Canyons on the east slope of the Panamint Range. In the mine area are numerous bodies of talcose rock most of which are confined to an area of about half a square mile. These bodies are covered by 14 claims which were located about 1940 by Owen Montgomery and Harrison P. Gower (address: 4835 Forman Ave., North Hollywood, California). They were leased shortly thereafter to the Sierra Talc Company, 1608 Huntington Dr., South Pasadena, California, the present operators. The claims are in approximately sec. 22 R. 47 E., T. 22 S., (proj.) M.D.M. The mine was worked continuously for a three-year period during World War II when the use of very high quality talc (steatite-grade) was restricted to the manufacture of electrical insulators, and talc from the Montgomery mine was used as a substitute for steatite talc in non-strategic uses. Since 1946, it has been worked briefly and intermittently; only assessment work has been done in recent years. Through 1959, the mine had yielded about 6000 tons of commercial talc.

On the north side of the ridge, quartzite of the lower part of the Crystal Spring Formation rests with depositional contact upon older metamorphic rocks and dips gently to moderately northward. On the crest and upper slopes of the ridge, irregular bodies of diabase are intrusive into dolomite of the carbonate member. Also in the mine area are several bodies of intrusive volcanic rock of intermediate composition. Because most of the diabase bodies crosscut the dolomite, the talc bodies are much more irregularly distributed and less continuous than those that border the lower diabase sill elsewhere in the region.

Most of the talc bodies occur as variously oriented septa within the diabase. Others occur along diabase-dolomite contacts. Still others extend into dolomite from a cross cutting body of diabase. These form tongue-like bodies and are parallel with the bedding.

Talc has been mined at two localities, both high on the south wall of Galena Canyon. One is several hundred feet east of a drainage divide that separates tributaries of Galena and Warm Spring Canyons and at nearly the same elevation as the divide. The other is about 1700 feet southeast of the divide and about 450 feet higher. The lower deposit is poorly exposed but is part of a silicated zone that has altered from siliceous dolomite along the upper margin of a diabase sill. The zone strikes east to northeastward and dips gently south to southeastward. The exposures suggest that it is at least 1200 feet in strike-length, but the contained bodies of mineable talc probably are much less continuous.

All of the mining at the lower locality has been confined to a layer in contact with the sill and composed of white, blocky to friable moderately well-foliated, talc-rich rock. It has a maximum observed thickness of about 15 feet, but appears to pinch and swell. At least two other talcose bodies, 4 to 8 feet thick and of possible commercial interest, lie higher in the zone, but remain unmined. The bodies are separated by darker silicate-carbonate rock of no present value. Carbonate seams are locally abundant in each of the rock types.

The lower workings, in plan, lie within an area about 200 feet square. They consist essentially of an irregularly east-trending drift, about 250 feet long, connected to the surface at its west end by a short, south-trending adit, and joined about 100 feet east of the adit to a cross-cut and a winze each trending south-southeast and each about 150 feet long. The winze has an over-all slope of about 11°. Most of the salable talc has been removed from the drift, winze, and gently inclined stopes connected to the bottom of the winze. The limits of the main body and of the other talc bodies of possible commercial interest remain undetermined.

The upper deposit is in one of the rare occurrences of silicated rock that is associated with a cross-cutting body of diabase rather than a sill. The margin of the diabase body strikes eastward and is bordered on the north by an intact mass of Crystal Spring carbonate strata. Here, as elsewhere, the zone of silication that contains the bodies of commercial talc is an alteration of the lower strata of the carbonate member, but it forms a tongue the long dimension of which trends northeastward at an angle of about 30° with the diabase contact.

At this locality, as at others in the Warm Spring Canyon-Galena Canyon area, the zone of silicated rock averages a few tens of feet in thickness. This zone is about 500 feet in exposed length, strikes east-northeastward and dips about 20° southeastward. Here, too, the talc of commercial interest occurs in two or more layers, the lowest of which has been the most extensively mined. Separating these layers are layers of a darker-colored silicate-carbonate rock. Also bordering the margin of the diabase body, but higher in the carbonate member, are tongues of green tremolitic rock oriented parallel with the strata.

The two principal layers of talc each average 10 to 15 feet in thickness and are separated by 8 to 12 feet of the darker rock. The talc is generally blocky, but crudely foliated, and tinted gray to green. The lower layer has been followed underground, from a point near its most southeasterly exposure, by means of a gently inclined, southeast-trending shaft, from the bottom of which a 300-foot drift extends southeastward to eastward. A raise has been driven north-northeastward from a point near the eastern end of the drift. Tongues of silicated rock similar, in appearance and geologic setting, to those just described are exposed about 300 feet to the north of the upper workings and about 150 feet lower on the slope. These remain nearly unexplored but appear to contain significant reserves of commercial talc. These and the rocks associated with them are probably a down-faulted segment of the units in the higher exposures. Numerous other bodies of talc-bearing rock are scattered through the mine area, but none has yet been shown to be as large as those already noted. Most are poorly exposed septum within diabase and have been explored only by shallow pits and trenches.

Omega mine. The Omega mine, one of the most recently opened talc properties in the Death Valley region, is in the western part of the talc-bearing belt in the northwestern Kingston Range. The mine property consists of two patented claims owned by the D. E. McLaughlin Estate, 1911 Mills Tower Building, San Francisco, and leased to the Pomona Tile Manufacturing Company, 629 North La Brea Avenue, Los Angeles. The claims are in sec. 35 (projected), T. 20 N., R. 9 E., S.B.M. They are part of a large group originally located to cover the nearby Beck iron deposits.

The mine was first worked by the Pomona Talc Company in 1956–57 when about 1500 tons of talc was sold to the Pomona Tile Company, a wholly different concern. Since late 1957, the Pomona Tile Company has been the sole operator and, through 1959, has produced an additional 10,000 tons.

A single body of talc-bearing alteration rock is exposed along two small northwest-trending ridges on the south side of lower Beck Canyon. This body strikes northwestward, dips steeply to moderately northeastward, and can be traced laterally for about 3000 feet. It terminates to the northwest and southeast against northeast-trending cross faults. These faults bound a block which, within the area of plate 2, contains a nearly complete section of the Crystal Spring Formation. Here, the quartzite of the lower part of the formation is bordered on the south by the intrusive margin of the large body of quartz monzonite that underlies Kingston Peak to the south.

The diabase sill, that ordinarily lies at the base of the carbonate member, is present but is here separated from the member by a layer of quartzite and shale, 10 to 30 feet thick. The talc-bearing body, as elsewhere, is an alteration of dolomite strata at the base of the carbonate member, and the quartzite-shale layer forms its footwall. The ridges on which the body is exposed are of rather low relief, and the trace of the body, in general, slopes gently northwestward through a vertical distance of about 400 feet.

The body of altered rock ranges in thickness from 50 to 100 feet, but considerably less than half of the material uncovered to date is recognized as being of commercial grade by the operator. The useable talc occurs as pods and lenses, as much as several hundred feet long and 30 feet wide, within the subcommercial material. The highest quality material occurs along or near the footwall of the zone. It consists of white blocky to highly friable rock composed mostly of the mineral talc, locally rich in tremolite and with a low proportion of limy material. The material farther from the footwall is higher in lime. The waste rock is generally colored various shades of gray green and brown, and much of it is said by the operators to be rich in alumina and alkalies.

Northwest of the main cut, the body of altered rock is hidden beneath alluvium for a distance of about 200 feet. Beyond the alluvium, however, the body extends for at least another 800 feet and appears comparable in thickness and composition with the southeastern part of the body.

Mining has been confined to a 1000-foot segment in the southeastern part of the body. Prior to 1960, all of the talc was removed from several open cuts, of irregular outline and spacing and at different elevations, the largest and lowest being about 200 feet long, 40 feet in maximum width and 30 feet in maximum depth. Underground mining was begun in 1960 and consists of a drift driven southeastward from the west end of the main cut and close to the footwall of the zone of alteration. Late in 1960, the drift was about 600 feet long and had been driven mainly in a body of commercial talc that appears to average about 8 feet in width.

Owlshead deposits. One of the least accessible of the talc deposits in the Death Valley region is on the northeast slope of the Owlshead Mountains about 2500 feet above the floor of the valley. It can be reached only by hiking from the base of the mountains. Claims have been located on the deposit, but little work has been done and the present ownership is unknown to the writer.

Exposed on the northeast slope of the Owlshead Mountains is a large mass composed of units of the Crystal Spring Formation. Near the crest of the mountains, quartzite strata low in the formation are in intrusive contact with the large body of granitic rock that forms the main mass of the mountains. Crystal Spring units are exposed on the slopes below the contact, dip steeply to moderately eastward to northeastward, and are essentially unbroken by faults.

The quartzite is overlain successively by strata of the purple shale member and the fine-grained quartzite member and a diabase sill which contains septa of variously altered strata of the carbonate member. The sill is at least 1200 feet thick and is the uppermost unit exposed in the slope.

The talc-bearing rock is confined to a body of altered carbonate rock that immediately underlies the sill and can be traced laterally for several hundred feet. It strikes eastward, dips about 50° northward, and is exposed on flat parts of the crests of two small ridges. The zone averages between 20 and 40 feet in thickness and consists mostly of incompletely altered carbonate strata and green tremolitic rock. White, well-foliated talc forms lenses and layers within the zone. Most of the talc appears to occur in bodies 5 feet or less wide and less than 200 feet in exposed length. The workings consist of a few small cuts and pits.

Panamint mine. The Panamint mine, west of the lower part of Warm Spring Canyon in the Panamint Range, and not to be confused with the Montgomery (Panamint) mine north of the canyon, was operated intermittently from 1952 through 1957, and has yielded 4,700 tons of talc. The mine property consists of 5 claims, most of which were located by Ernest Huhn in 1935. They were later acquired by the present owner, the Southern California Minerals Company, 320 South Mission Road, Los Angeles.

The mine area is in a group of small east-trending ridges that form the lower part of the Panamint Range front between Warm Spring Canyon on the north and Anvil Spring Canyon on the south. Exposed here is an irregular area of bedrock covering about half a square mile. Surrounding the area of bedrock is a dissected cover of Quaternary (?) rocks consisting of fanglomerate on the lower slopes and land-slid masses of Noonday Dolomite and Tertiary volcanic rocks on the higher slopes west of the mine area.

This window-like area of bedrock is underlain chiefly by diabase and dolomite of the Crystal Spring Formation. Although considerably faulted and folded in detail, the bedrock consists of essentially an east-tilted block, broadly folded into an east-plunging syncline. The dolomite, an unusually thick occurrence of the carbonate member, has been intruded by the diabase to form irregular sill-like bodies of various sizes.

In a broad arc, around the northwest, west, and southwest part of the exposed edge of the block are numerous bodies of talc-bearing rock that have altered from carbonate strata. Although the lower (quartzitic and shaly) part of the Crystal Spring Formation is unexposed, the altered strata appear to have been low in the carbonate member. Most of the bodies occur as septa within the diabase, but some occur along dolomite-diabase contacts, and some are enclosed in dolomite.

The most northerly of the exposures of talc-bearing rock on the Panamint claims are distributed for about half a mile along the south wall of the first small east-draining canyon south of Warm Spring Canyon. Here, the intrusive contacts between the diabase and dolomite of the carbonate member are especially irregular and extend southward beneath older Quaternary fanglomerate, which forms the south wall of the canyon. In the lower part of the canyon, the silicated rock is associated with a southwest-trending and southeast-dipping finger of diabase. Most of the silicated rock occurs in two bodies; one in a septum within the diabase body and about 500 feet in exposed length and composed mostly of green tremolitic rock; the other is beneath the diabase body and about 300 feet in exposed length and also appears to contain much waste rock.

In the upper part of the canyon, a talc-bearing body occurs along a west-trending contact between cherty dolomite above and diabase below. The body can be traced discontinuously along-strike for about 500 feet, ranges in dip from 15° southward to nearly horizontal, and is offset by several south-trending cross-faults. It appears to be as much as 15 feet thick and to contain a lower layer of thinly laminated generally blocky material and an upper layer of friable, schistose material. It also contains abundant waste rock in the form of incompletely silicated masses of carbonate material. At the lower (easterly) end of the body is a gently-inclined, south-trending shaft about 60 feet long. A 20-foot drift extends westward from the bottom of the shaft. These workings, the oldest on the Panamint property, were driven in the early 1950's and a small tonnage of talc was shipped from them.

Most of the talc thus far produced has been obtained from a deposit about 1000 feet south-southwest of the above-noted shaft. Here, a body of talc-bearing rock forms nearly a dip-slope on the northeast side of a small east-plunging ridge. This body strikes northwestward, dips moderately northeastward, and, in plan, is crudely circular with a diameter of about 300 feet. It appears to be part of a septum of silicated rock within diabase. The septum is of undetermined length, but is several tens of feet in maximum thickness. The commercial talc, although subordinate to other types of alteration rock, occurs in mineable layers, ten feet or more thick. The body was mined by means of an open cut in the mid-1950's.

About 2000 feet still farther southwest, are two talc-bearing septa within diabase. These are each several hundred feet long, as much as 30 feet thick, and consist mostly of green tremolitic rock. The rock of possible commercial value consists mostly of talc schist and occurs in layers as much as 5 feet thick. Numerous other bodies of silicated rock also are exposed in the mine area, but appear to be smaller and/or of lower grade than those already described.

Pongo mine. The Pongo talc deposit is exposed low on the west slope of the north part of the Saratoga Hills. It is about three miles north of Saratoga Spring and 1½ miles northwest of the Superior mine. It is covered by a single claim which is in sec. 22, T. 19 N., R. 5 E., S.B.M. The claim was originally located in the mid-1930's by Ernest Huhn who sunk a shallow shaft and abandoned the property. It was then acquired by Harvey B. Brown, 824 Lomita Road, San Bernardino, California, who in 1948 leased the claim to the Southern California Minerals Company, 320 South Mission Road, Los Angeles. This company, which in 1961 still held the lease, worked the deposit from 1948 to 1955 and obtained 12,554 tons of commercial talc. Since 1955, the deposit has been idle.

As the surface exposures of the Pongo deposit are poor and extend beneath alluvium and dune material to the north and south, its geologic setting is obscure. It appears to be a body of white silicate rock within a septum which is enclosed by diabase of the Crystal Spring Formation. Most of the septum consists of alteration rock of no present commercial value. The silication can be traced along-strike for several hundred feet and may be more extensive. The body that has yielded the commercial talc, as outlined by the underground workings, appears to be lenticular and extends down-dip for about 350 feet and along-strike for a maximum distance of 180 feet. This body, which has a footwall and a hanging wall of brown silicate-carbonate rock, strikes about N. 30° E. and dips southeastward from about 35° in the upper part to 20° in the lower part. Within the mine workings, it ranges in thickness from 6 to 12 feet, but pinches to 3 feet or less in the lower limits of the workings and terminates laterally in the brown silicate-carbonate rock.

Most of the mined material has consisted of thinly laminated to blocky rock composed largely of the mineral talc. Locally, it is tremolite rich and, in some places, contains abundant, pale-gray layers of carbonate material and brown, cross-cutting veinlets of calcite.

The principal mine workings consist of a shaft about 370 feet long and inclined southeastward, mostly within the talc body. From each of four levels, at slope distances of about 100, 170, 270, and 370 feet, a drift has been driven northeastward and southwestward for about equal distances on each side of the shaft. From the highest to the lowest, these drifts are about 130, 135, 180, and 140 feet respectively, in total length. Stopes connect them.

Rainbow mine. The Rainbow mine, the most recently opened of the productive talc operations in the southern Death Valley region, has penetrated a deposit low at the southern end of the west slope of the Saddle Peak Hills. The mine is about 3½ miles due east of Saratoga Spring and on the same group of claims that also contains the Caliente mine. These claims are in sec. 32 (projected), T. 19 N., R. 6 E., and sec. 5, T. 18 N., R. 6 E., S.B.M. They were located in the mid-1950's by H. E. and E. T. Baumunk and associates, 6521 Etiwanda Ave., Mira Loma, California, who, in 1956, leased them to the Sierra Talc Company, 1608 Huntington Drive, South Pasadena. This company has been the sole operator and, since opening the property in 1956, has produced 13,800 tons of talc through 1959.

The Rainbow, like most of the other productive deposits of commercial talc in the southern Death Valley region, occurs in an alteration zone along the upper margin of a diabase sill that underlies the carbonate member of the Crystal Spring Formation. It is unlike the others in that: (1) the commercial talc occurs in the upper part of a thick alteration zone, the rest of which consists of green tremolitic rock; and (2) the commercial talc, thus removed from the diabase contact, contains tremolite apparently as the only abundant silicate mineral.

The alteration zone strikes northward, and dips moderately eastward. It is exposed for a strike distance of about 1700 feet across several west-plunging ridges (fig. 14). It extends beneath alluvium to the south and to the north beneath Beck Spring Dolomite, which rests upon the Crystal Spring Formation with a discordant (fault?) contact. A fault block, containing a northerly extension of the zone, lies several hundred feet north of the point of overlap by the Beck Spring Dolomite. This segment of the zone is about 700 feet long.

In the mine area, the zone of alteration is several tens of feet thick and the upper part, from which the commercial talc is mined, is 20 to 30 feet thick. The rock in the upper part is white, blocky, and very tough. It consists mostly of mixed carbonate and tremolite in various proportions. The operators consider nearly the entire thickness to be of commercial value and recognize two grades based on the soluble lime content, as indicated by the reaction to hydrochloric acid. In general, each grade occurs in layers four to eight feet thick and 100 or more feet long. These are mined selectively, between a footwall of green tremolitic rock and a hanging wall of partly silicated dolomite.

The deposit has been mined through an adit driven north-northeastward from the south side of a ridge. The adit level is about 110 feet vertically and 185 feet down-dip from the high point on the surface exposures of the talc body. In mid-1961, the adit was about 700 feet long, and stopes extended to the surface for most of this length. In the northern half of these workings, a sub-level lies about midway between the adit and the surface. Although the rock is difficult to drill, it is not subject to caving and almost no timber has been used to date.

Rogers mine. The Rogers mine is near the base of the west slope of the Kingston Range and about ¾ of a mile south of the road that extends southeastward and eastward from Tecopa and through Beck Canyon in the Kingston Range. The mine property consists of a group of six patented and contiguous claims. The group lies mostly within sec. 33, T. 20 N., R. 9 E., S.B.M., (projected), but which is partly in

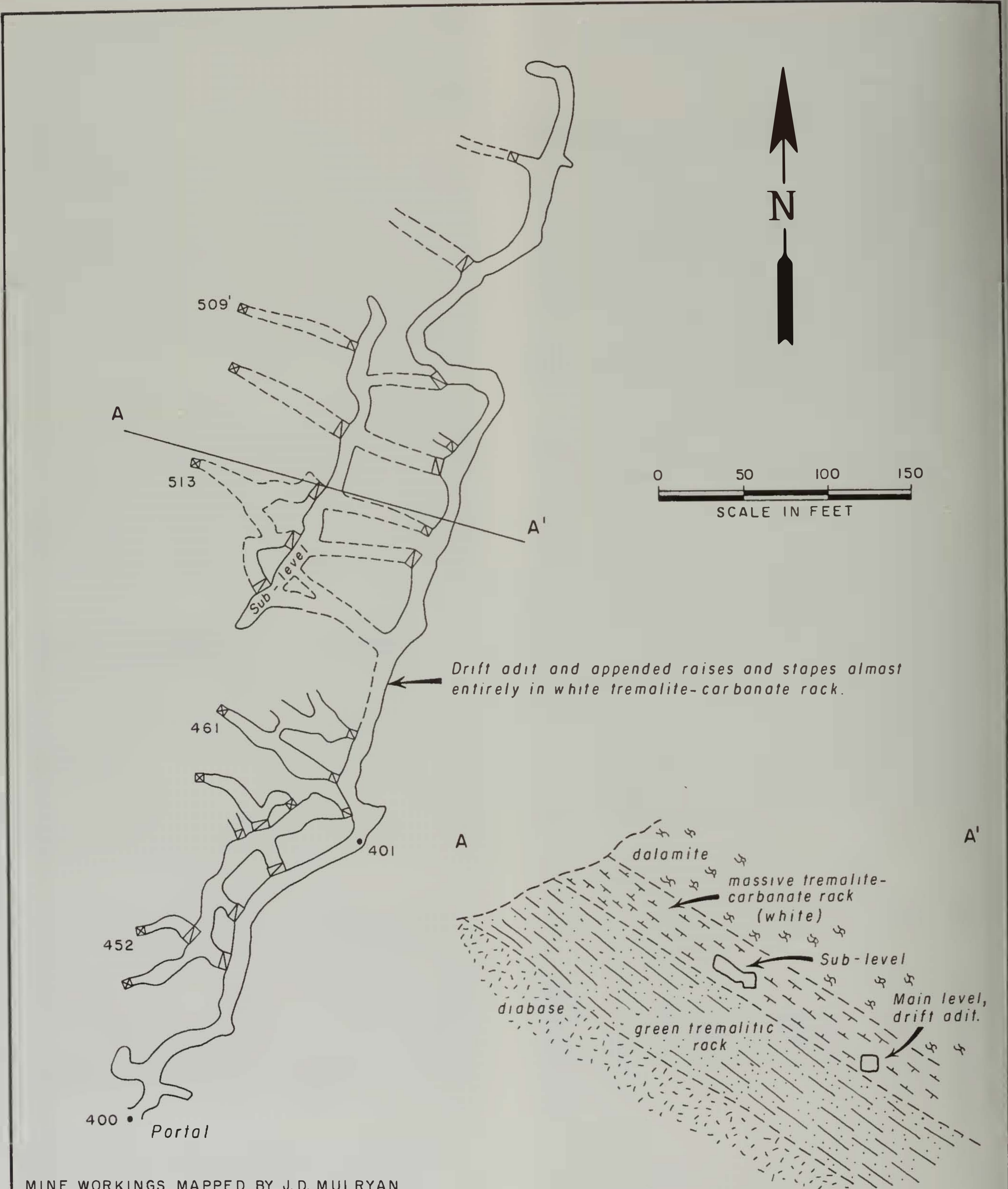

Figure 14. Map of underground workings of Rainbow mine and geologic cross section.

sec. 4, T. 19 N., R. 9 E., S.B.M. (projected). The claims are owned by International Pipe and Ceramic Corp., 2901 Los Feliz Boulevard, Los Angeles, California.

Phota 15. Aerial view eastward of sauthern end af Saddle Peak lills, shawing east-dipping units af later Precambrian Crystal Spring armatian an near spur. Dark band af diabase is overlain by light-olared zone af alteratian that cantains the Rainbaw deposit. Caliente epasit is in septum near lawer end af spur.

The numerous trenches and cuts, the several shallow hafts, and the two adits that constitute the mine work-ngs, were developed mainly in the period 1940–42 vhen several hundred tons of talc were shipped. The property has been idle since then.

The talc bodies on the Rogers property are the most westerly of the exposed occurrences of a faulted talc-bearing zone that has been worked at several other ocalities to the east. The Rogers mine workings lie along two segments of the zone. Each trends north-westward and dips moderately northeastward, and is fault-bounded at both ends (pl. 1A). Each is discontinuously exposed for a strike distance of about 1700 feet but lies, largely hidden, beneath several or more feet of talus. The mineable bodies of talc apparently are much less extensive than the zone of alteration.

The more northwesterly segment of the talc-bearing zone is exposed along the southeast side of a ridge which is underlain mostly by dolomite of the carbonate member of the Crystal Spring Formation. In the lower part of the member is a seemingly continuous layer of silicated rock. Through a lateral distance of about 600 feet, extending from the southeasterly termination of the layer, it ranges from 6 to 12 feet in exposed thickness and is relatively unfaulted. Here, the layer consists mostly of thinly laminated talc rock and talc schist but contains interlayers of brown silicated rock and carbonate-rich material. In the northwestern part of this segment, the layer is offset by several cross-faults, and several of its surface exposures show abundant seams of carbonate that lie parallel to the layering. At the southeast end of the layer, a diabase sill forms the footwall, but, elsewhere, the layer is separated from the sill by a 20- to 30-foot thickness of quartzite and siliceous dolomite.

Bodies of talcose rocks, about 20 feet stratigraphically above the lower layer, are exposed in several places, but appear to contain too much carbonate material to be of commercial interest. The rest of the zone contains much brown silicated rock.

The more promising (southeastern) part of the lower layer has been penetrated by an adit driven N. 45° E. about 400 feet at a level several tens of feet beneath the outcrop. The adit is joined to the surface by a raise, inclined about 40° northeast and driven in talc, but no level workings extend from the adit. About 700 feet northwest of these workings, a drift adit extending about 60 feet southeastward into the lower body has exposed talc with abundant lenticles of gray carbonate material. The other workings consist of about 15 trenches, cuts, and shallow shafts.

The more southeasterly segment of the talc-bearing zone at the Rogers mine is exposed on the southeast side of a hill and is about 400 feet higher topographically than the segment described above (pl. 1A). At least half of the trace of this occurrence is covered by thick talus. Exposures in several scattered cuts suggest that much of the talc is in bodies that are less than 5 feet thick or are too highly faulted to be mined profitably. A talc layer near the southeastern end of the segment, however, is worthy of additional exploration. This layer, which has a diabase footwall, appears to be 6 to 10 feet thick and may be 400 feet or more long.

Saratoga mine. Collectively designated as the Saratoga mine are three groups of workings which are covered by 6 claims along the lower west slope of the Saratoga Hills which form part of the east border of southern Death Valley. The claims are owned by H. C. Brown, 824 Lomita Road, San Bernardino, California, and are under lease to the Southern California Minerals Company, 320 South Mission Road, Los Angeles, California. They are in sec. 26 and 35 (projected), T. 19 N., R. 5 E., S.B.M. Each of the workings is small. Since the first shipments in the mid-1940's, they have yielded a total of 5000 to 10,000 tons of talc.

The most northerly of the workings were leased and operated in the period 1944–45 by the Champco Minerals Company. About 1000 tons of talc was mined by this company and was custom-milled at Rosamond, California. Then the property was idle until 1949, when workings were opened at the southern end of the property by the Saratoga Talc Company. These were worked on a small scale until 1954 and have been idle since then. The central workings were opened by the present lessee in 1955 and continue to be intermittently operated.

In the Saratoga mine area, the talc bodies of commercial interest form part of a very elongate septum within the lower diabase sill of the Crystal Spring Formation. The septum is exposed on west-plunging ridges but lies partly hidden beneath alluvium in the intervening stream channels. It strikes northward, dips gently to moderately eastward, and can be traced laterally for about one and a quarter miles. Both northward and southward it extends beneath alluvium. The septum appears to average between 30 and 50 feet in thickness and locally is as much as 100 feet thick. It consists of strata, now extensively silicated, that once formed the lower part of the carbonate member of the Crystal Spring Formation. The silication commonly extends through the entire thickness of the

Photo 16. View northward of northern part of Sarotoga tolc deposit. White layer on far hillslope projects beneath alluvium on left to exposures in foreground, ond morks troce of septum in diabose sill (dark). Septum contains, elongate, lenticular bodies of commerciol talc associated with bodies of other silicated rocks, dolomite, and quartzite. Hill slope in left-distonce is underlain by eost-dipping quartzite ond shale in lower part of Crystol Spring Formation. Originol ond most northerly workings are on far hill slope; latest and central workings are in foreground.

septum, but dolomite and quartzite are locally abundant. The carbonate strata above the sill also consist of dolomite but are only slightly silicated at the contact.

Occupying most of the volume of the septum, is a green tremolitic (?) waste rock. The mined material has consisted of white, blocky to well-foliated, and friable rock rich in the mineral talc. The talcose rock generally occurs as a single layer in the upper half of the septum and ordinarily lies between walls of the green alteration rock. It persists laterally for most of the length of the septum but commonly is too thin or too intimately mixed with sub-commercial material to be profitably mined. In some places it pinches out altogether between walls of the green alteration rock. Although incompletely explored, the layer shows thicknesses of 4 to 20 feet and persists laterally for at least a few hundred feet.

At the northern workings, the septum dips gently eastward. Here, the talcose layer is at least 300 feet long and as much as 10 feet thick. It is irregular in thickness, however, and mixed with waste-rock, including a thin sill of diabase. It is exposed along the face of an open cut, which is about 200 feet long, high on the southwest slope of a small ridge. Irregular level workings are joined to the cut and extend into the talc body for a few tens of feet and along-strike about 100 feet.

The most southerly workings consist of a shaft, with appended levels, low on the north slope of another west-trending ridge. Here, the talcose layer shows a maximum thickness of about 8 feet and is bordered, top and bottom, by the green alteration rock. It can be traced laterally at the surface for about 500 feet but may be more extensive. In the shaft, it has been followed down-dip for about 200 feet and laterally for about 100 feet. At the collar, the shaft is inclined S. 65 E. at a 40°–45° angle and, below the 50-foot level, S. 40 E. at a 30°–35° angle. Workings at the 50, 100, and 150-foot levels extend both north-northeast and south-southwest for average distances of about 50 feet, to points where the layer thins to two feet or less. At the 150-foot level, the body is very irregular.

The central and most recently operated workings also center about a shaft on the lower north slope of a ridge. The septum here is about 30 feet thick and consists mostly of talcose rock and the green alteration rock. Dolomite and quartzite also are abundant. These various units strike northward and dip 35° to 65° eastward. Most of the talcose rock is distributed discontinuously in the upper part of the septum. The most continuous exposure of talc-rich rock extends from the shaft collar southward along an open cut for bout 200 feet. This body is about 20 feet in maximum bserved thickness and consists of friable to blocky naterial. It is separated from the diabase hanging wall y a layer of green rock of irregular thickness and ; underlain by a layer of mixed dolomite, quartzite, nd dark silicate-carbonate rock. The shaft, inclined 0° to 35° eastward, is about 80 feet long. For the ipper 50 feet, it follows the talc layer, which here s 8 to 10 feet in average thickness. At the 50-foot evel, the talc pinches out between the wall rocks, nainly by a thickening of the green rock in the hanging wall. A 40-foot east-trending cross-cut at the bottom of the shaft has penetrated only waste rock, nostly of the green variety.

Sheep Creek (Western Atlas) mine. The presence of a talc deposit in the lower part of Sheep Creek Canyon (sec. 5, T. 17 N., R. 6 E., S.B.M., projected) on the north slope of the Avawatz Mountains has been known for many years (Diller, 1914, p. 157–160), and the deposit was included in a group of 3 claims which, in 1930, were patented by the present owner, the Avawatz Salt and Gypsum Company, 2545 Raleigh Drive, San Marino. The deposit remained little explored until 1948 when the property was leased to the now inactive Western Atlas Company. This company engaged in underground exploratory work at the western end of the principal body but shipped little or no commercial talc. In late 1951, the property was leased by the present operator, the Sierra Talc Company, 1608 Huntington Drive, South Pasadena, which, in small scale but nearly continuous operations, had produced 20,000 tons of commercial talc through 1959.

The mining has been confined to a zone of alteration that lies along the north side of a west-trending and steeply-dipping diabase sill in the Crystal Spring Formation (pl. 1D) (see also general description of talc in northern Avawatz Mountains). Although the sill and bordering rocks are much sheared and intimately fractured, this talc-bearing zone is essentially intact along a strike-length of about 1800 feet. In mid-1960, it had been followed underground almost continuously along strike for about 1000 feet.

Nearly all of the talc-bearing rock of commercial interest lies within 30 feet of the margin of the diabase sill. Here, such rock forms white layers that alternate with pale green to pale gray subcommercial alteration rock.

The zone trends westward and is approximately vertical in average dip, but dips moderately northward at its western end. Its internal structure is as yet incompletely understood. At least in the western part of the body, the commercial talc occurs in two nearly parallel layers, one adjacent to the diabase and the other 30 to 65 feet north of the diabase. The layer next to the diabase averages about 8 feet in observed thickness and pinches and swells from a minimum of a few inches to a maximum of about 12 feet. The other layer ranges in thickness from a few feet to 20 feet and averages about 10 feet. Both consist of blocky to foliated rock rich in the mineral talc. The more north-

Photo 17. View westward of easternmost exposure of talc body in Sheep Creek, northern Avawatz Mountains. Vertically-dipping units of later Precambrian Crystal Spring Formation, tops to right, consist of diabase sill to left of white altered zone, and thin-bedded quartzite to right.

erly of the two layers appears to be the more continuous and may persist throughout the length of the zone. Locally the layer next to the sill is cut out by irregularities in the margin of the sill and probably by faulting along the margin. In at least one place, the zone contains three or more parallel bodies of commercial talc.

In mid-1960, the deposit had been penetrated by drifts for most of its known length. As little stoping has been done, this work has been considered as mainly exploratory, but, since 1952, most of the material removed during the drifting has been sold as commercial talc.

The western adit is a drift driven in the period of September 1948 to May 1949 by the Western Atlas Company. It is about 160 feet long, trends about S. 70° E. from the west slope of a small, north-trending ridge and is joined to the surface by shallow stopes. The workings follow a layer of talcose rock along the northern margin of the diabase sill. The layer dips irregularly, pinches and swells markedly, and is as much as 20 feet thick. The material mined proved to be then mostly unsalable, and the operation was shut down.

The eastern adit was started early in 1952, soon after the property was leased to the Sierra Talc Company. The portal is on the steep west wall of the canyon and about 40 feet above the alluvium in the channel. An earlier adit, driven from the level of the alluvium, follows the talc-bearing zone for a distance of about 150 feet, but its portal is now covered by dump material from the higher adit.

Near the portal, the higher adit crosscuts the two previously noted talc layers; two nearly parallel drifts extend from the adit, one along each layer. The southern drift is about 150 feet long, and the northern one is about 300 feet long and is joined to the surface by several raises. Work in this part of the mine was suspended in 1957 when a rock slide damaged the ore bin.

In 1956, the central and presently used adit was opened and was driven 285 feet southward to penetrate the northerly layer, but at a level about 80 feet lower than that of the eastern workings. A drift follows this layer for about 475 feet eastward, and, near its east face, is joined by a raise to the north drift in the workings to the east. At this level also, the talc layer next to the diabase has been intersected by a crosscut, about 280 feet east of the end of the adit, and mined for a strike distance of about 120 feet eastward. A steep raise on this layer extends westward from the end of the crosscut, but otherwise its westerly extent remains undetermined. To the west of the crosscut adit, the more northerly body has been followed by a drift estimated to be 210 feet long in mid-1960.

Other bodies of talc-bearing alteration rock are exposed on the hillslope west of the body that contains the mine workings. These are associated with numerous small sills and pods of diabase and discontinuous layers of sedimentary carbonate rock. Consequently, the bodies of alteration rock are relatively small and irregular.

Smith (Tecopa) mine. The Smith mine lies low on the northwest slope of the Kingston Range and about half a mile south of the mouth of Beck Canyon which drains westward from the central part of the range. The mine property consists of 2 claims both owned by the Sierra Talc Company, 1608 Huntington Dr., South Pasadena, California. The claims are in sec. 34 (projected), T. 20 N., R. 9 E., S.B.M.

These claims were located, probably in the early 1930's by a Mr. Smith, who sold them to the present owner in 1934 or 1935. From 1935, when the first talc was shipped, until 1954, the mine was in almost continuous operation. It has been idle since then. The output probably totals at least 25,000 tons.

At the Smith mine, the talc-bearing zone is in one of several adjacent blocks which are bounded by northeast-trending cross faults and which contain the Omega, Crystal Spring, and Vulcan deposits to the east of the Smith mine (pl.1A). Within the block that contains the Smith deposit, units of the Crystal Spring Formation strike eastward to east-northeastward, but are greatly complicated in detail by minor faults and by numerous sills and irregular bodies of rhyolite. The talc bodies occur near the base of the carbonate member which, in this fault block, extends along-strike for about 4000 feet.

In the mine area, the talc bodies are much less continuous than the carbonate member and are exposed, from place to place, along-strike for a distance of about 1800 feet. At each end, the talc-bearing zone terminates against a rhyolite body. Most of the talc occurs within 40 feet of the base of the dolomite. Some lies along the contact between the dolomite and quartzite-shale unit which underlies the dolomite. Other bodies are enclosed entirely by dolomite. Although diabase, in sill-like and irregular bodies, is abundant in the area, only locally is it in contact with the talc. Ordinarily, the diabase is separated from the lower talc bodies by a layer of quartzite and shale.

Most of the output of the Smith mine has been obtained from two bodies, one on each side of a small, north-draining canyon that cuts through the carbonate member. Both pinch and swell from thicknesses of a fraction of an inch to as much as 25 feet. Both also have been made discontinuous by the intrusion of rhyolite bodies. Mining has been confined mostly to the lenticular bodies, which consist of very white material, rich in the mineral talc, and in sharp contact with the bordering dolomite. The talc is generally well foliated and friable, but blocky talc is common, particularly in the centers of the lenses.

The mine workings consist of two groups, one on each side of the small canyon. The workings west of the canyon (pl. 1A) were the first opened and have been made generally inaccessible by caving. Here, the more westerly of the two principal bodies has been penetrated by a 50-foot shaft, inclined about 60° and bearing west-southwest, parallel with the strike of the body. From the bottom of the shaft, a drift extends in the same direction for at least 500 feet. Mine maps and the distribution of caved stopes that extend to the

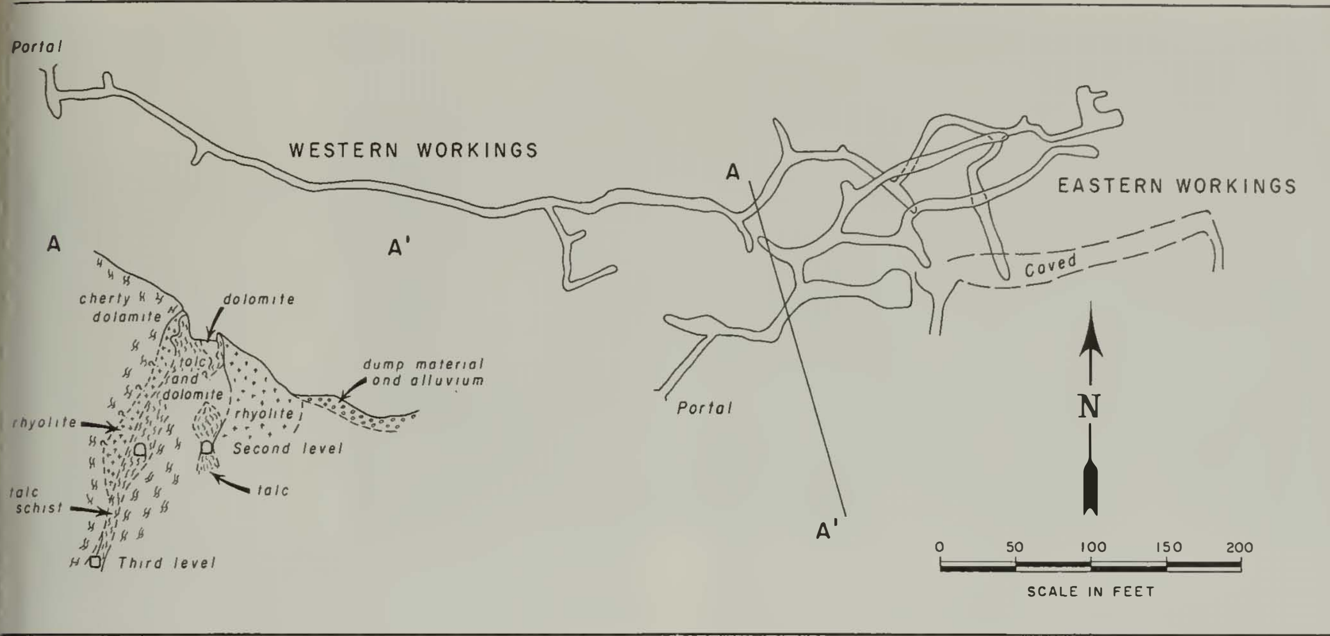

Figure 15. Map of Smith (Tecopa) mine.

surface suggest that talc was mined almost continuously for at least 400 feet along-strike from the bottom of the shaft and stoped above the shaft for a maximum slope distance of about 180 feet. Both diabase and quartzite lie along the footwall of the body. At the surface, the body dips about 65° northwestward, but it is said by the operators to flatten and thin markedly with depth.

Photo 18. View northwestward showing talc-bearing zone at Smith (Tecopa) mine in foreground and southern end of Nopah Range in middle distance. Zone dips northward and lies at base of ridge-forming carbonate member of Crystal Spring Formation. Original mine workings are on far slope; later workings are in foreground.

Another body of talc, also on the west side of the canyon, and about 100 feet north of the principal body, has been followed by a 130-foot drift-adit. This body appears to have formed within the dolomite. The adit is at the same level as the aforementioned drift and is joined to it by means of a cross-cut. Short stopes extend upward from the drift-adit, but the body apparently proved to be much smaller than the more southerly one. All of the work west of the canyon was done prior to 1942.

Beginning about 1942, operations were shifted to the east side of the canyon. Here, the talc-bearing zone has been penetrated at three levels. The highest and most easterly is a short north-trending adit from which drifts, now caved, extend for about 200 feet to the east and 100 feet or more to the west. The portal of the second level is about 175 feet west-southwest and 35 feet lower than the portal of the first. The second level consists of a group of irregularly-branching workings, mostly drifts and also now largely caved, which extend maximum distances from the portal of about 325 feet east-northeastward and 100 feet westward. The portal of the third level is about 450 feet west-northwest of the portal of the second and 70 feet lower. The third level consists essentially of a drift adit and is about 700 feet long. Although the zone of alteration is relatively continuous in these easterly workings, nearly all of the talc removed from them has been taken from a single body reported by the operator to be about 80 feet long, 8 feet in average width, and to extend from the surface through the lowest level. This body is enclosed entirely by dolomite. Another body lies a few tens of feet to the south but has been extensively intruded by bodies of rhyolite and has yielded very little talc.

Snow White (Kingston No. 1) deposit. The Snow White deposit is in the northeastern part of the Kingston Range, about 3 miles east of Horse Thief Springs and 2000 feet southeast of the southern workings of the Excelsior mine. The deposit is covered by a single claim which is owned by E. M. and S. E. Funk and associates, Nipton, California, and is in sec. 31 (projected) T. 20 N., R. 11 E., S.B.M. Although extensively prospected at various times since the late 1940's, little or no talc has been shipped. The latest development work was done in 1957 and 1958 when the property was leased by the Victorville Lime Rock Company.

The Snow White deposit, which strikes west-northwestward and dips moderately northward, is in a segment of the same talc-bearing zone that contains the Excelsior mine workings to the west and northwest. This segment is separated from the larger part of the zone by a northeast-trending fault and has been displaced northeastward an apparent distance of about 1200 feet. To the southeast, the zone terminates against another northeast-trending fault by which it is brought into contact with strata of the stratigraphically higher Kingston Peak Formation. A possible extension of the zone on the opposite side of this fault would lie about 4000 feet to the southwest and beneath alluvium (pl. 1C).

The Snow White segment of the talc-bearing zon is exposed on a southeast slope, the long dimension o the deposit being nearly normal to the contours an the west end about 250 feet higher than the east enc The segment is 50 to 100 feet thick and, in plan, i about 1200 feet long. It is underlain by a diabase sil but its eastern part is separated from the diabase by layer of dolomite. The zone is overlain by quartzit and dolomite of the upper units of the Crystal Sprin Formation, indicating that nearly the full thickness o the carbonate member of the formation has been silicated.

Here, the zone consists mostly of white silicate rock of which well-foliated talc schist is the mos abundant type. It also contains abundant layers an irregular masses of green alteration rock and smal bodies of diabase. Much of the white rock is staine with manganese minerals and/or iron oxides. The rocl also commonly contains a high proportion of carbonate mineral. Nevertheless, the zone also appears t contain bodies of commercial-grade talc 5 to 20 fee thick and 100 feet or more long.

The Snow White deposit was first explored by means of shallow pits and a short drift-adit driver westward from the lower part of the slope. In the lat 1950's, the zone was extensively uncovered by bulldozing, and an attempt was made to mine the talc from open pits. The work of the Victorville Lime Rock Company consisted of underground exploration by means of a drift-adit, now covered.

Superior mine. The Superior mine, one of the more productive and systematically developed talc operations in the Death Valley region, is in the central part of the Saratoga Hills and a few hundred feet above the floor of southern Death Valley. The mine area is covered by three claims, in secs. 25 and 26 (projected) T. 19 N., R. 5 E., S.B.M., and owned by Southern California Minerals Company, 320 South Mission Road, Los Angeles. The mine has been operated only by this company. Since mining began in 1940, it has been in nearly continuous operation and had yielded about 141,000 tons of commercial talc through 1959. Water for mining is obtained from Saratoga Spring about 2½ miles to the southwest.

The Superior mine lies athwart a drainage divide on the north-trending crest of the hills. Here the characteristic units of the Crystal Spring Formation, including the talc-bearing zone, strike about N. 40° E. and dip moderately to the southeast in normal sequence (Wright, 1952). The talc deposit, about which all of the mining has centered, differs from most of the others in the region in that it lies beneath, instead of above, the sill that has been intruded near the base of the carbonate member. Here, the sill occurs a few tens of feet above the base of the member, thus bringing into sub-sill position strata susceptible to silication. A zone of silication also occurs along the upper margins of the sill, but it contains a higher proportion of subcommercial material than is present in the lower zone and remains nearly unexplored.

Photo 19. View southwestward of Superior mine area and southwest-dipping units of Pahrump Group. Dark exposures on lower slopes (above and below road) mark diabase sill in Crystal Spring Formation. Principal talc-bearing zone is exposed at base of sill.

The surface exposures of the Superior deposit trend northeastward from a point on a northwest-facing hillslope, through the drainage divide and on to a southeast-facing hillslope. These exposures show that, at or near the surface, mineable thicknesses of commercial grade talc extend laterally for at least 1500 feet, that the zone has a maximum thickness of 75 feet southwest of the divide, and that it tapers in both directions. The zone terminates southwestward against diabase and in an area of structural complexity.

Within 250 feet of the southwestern end is a constriction where the southwestern segment appears to have been offset a few tens of feet northwestward. The talc in this segment is about 10 feet in average thickness. Although there is no obvious break in the nearby strata, underground exposures of the constriction show it to be a cross-fault and the workings terminate against it. The possibility exists, therefore, that a mineable, downward extension of the southwestern segment lies beyond the fault.

The northeastern end of the deposit has not been located with certainty, but at the surface the silicated zone pinches to a thickness of a few feet in the most northeasterly exposures. This pinching also has been detected underground along a line that plunges gently southward to the lowest of the seven mine levels, which is a slope-distance of about 550 feet from the exposures in the drainage divide. Consequently, at each successively lower level, talc has been mined a shorter distance to the northeast. The underground workings, however, have penetrated only a few feet northeast of this plunging line of thinning, so its significance remains undetermined, and talc in commercial concentrations may well lie to the northeast of this line.

In the underground workings, the proved deposit of commercial talc is about 1400 feet long in the higher levels and 1100 feet long on the sixth level, which is a slope-distance of 470 feet beneath the drainage divide. The general dip of the deposit steepens from about 20° SE. at the southwest end to about 60° SE. at the northeast end.

The Superior deposit consists predominantly of soft, friable and very white talc schist, which locally is associated with thinly-bedded talcose rock that breaks into blocky masses. As both types have essentially the same commercial characteristics, they are mined non-selectively. Through most of the deposit, such commercial material forms a single layer directly beneath the diabase sill. But in the central-upper part of the deposit is a bulge that is characterized by two layers of the talc schist separated by a layer of tough, massive, tremolitic rock. The margins of the bulge plunge southwestward, the eastern margins gently and the western margins steeply, so that the bulge also tapers to the southwest. This apparently unique, three-ply structure is exposed at the surface from the vicinity of the shaft southwestward for about 400 feet. On the sixth level, only a single layer of talc schist has been found.

The tremolitic layer averages about 40 feet in thickness and forms firm walls for the bodies of relatively soft talc that bound it. In most places, the juncture of the bounding layers of talc forms the lateral termination of the tremolitic layer, but, locally, it terminates against diabase of the hanging wall.

The tremolitic layer consists mostly of a pale green to pale gray mixture of tremolite and carbonate material which the operators consider as waste. On each side of the layer, however, is a two- to four-foot thickness of white, highly tremolitic rock of probable commercial interest. To date this tremolitic material remains unmined, mainly because the bodies are thin and difficult to remove.

The talcose layer that lies beneath the tremolitic layer and is farthest from the diabase hanging wall has been designated by the mine operators as the "Number One vein", and the one between the tremolitic layer and the diabase as the "Number Two vein". The Number One vein ranges in thickness from a few inches to as much as 30 feet and pinches and swells in conformity with rolls in the dolomite footwall. It contains local horses of waste rock, but, in general, it is persistently 5 to 15 feet thick. The Number Two vein is about 12 feet in maximum thickness and is thinner overall than the other. In some places it pinches out altogether, but undulations in its walls are uncommon.

Although the operators consider both layers to be identical in a commercial sense, they recognize slight differences in the appearance of the contained talc.

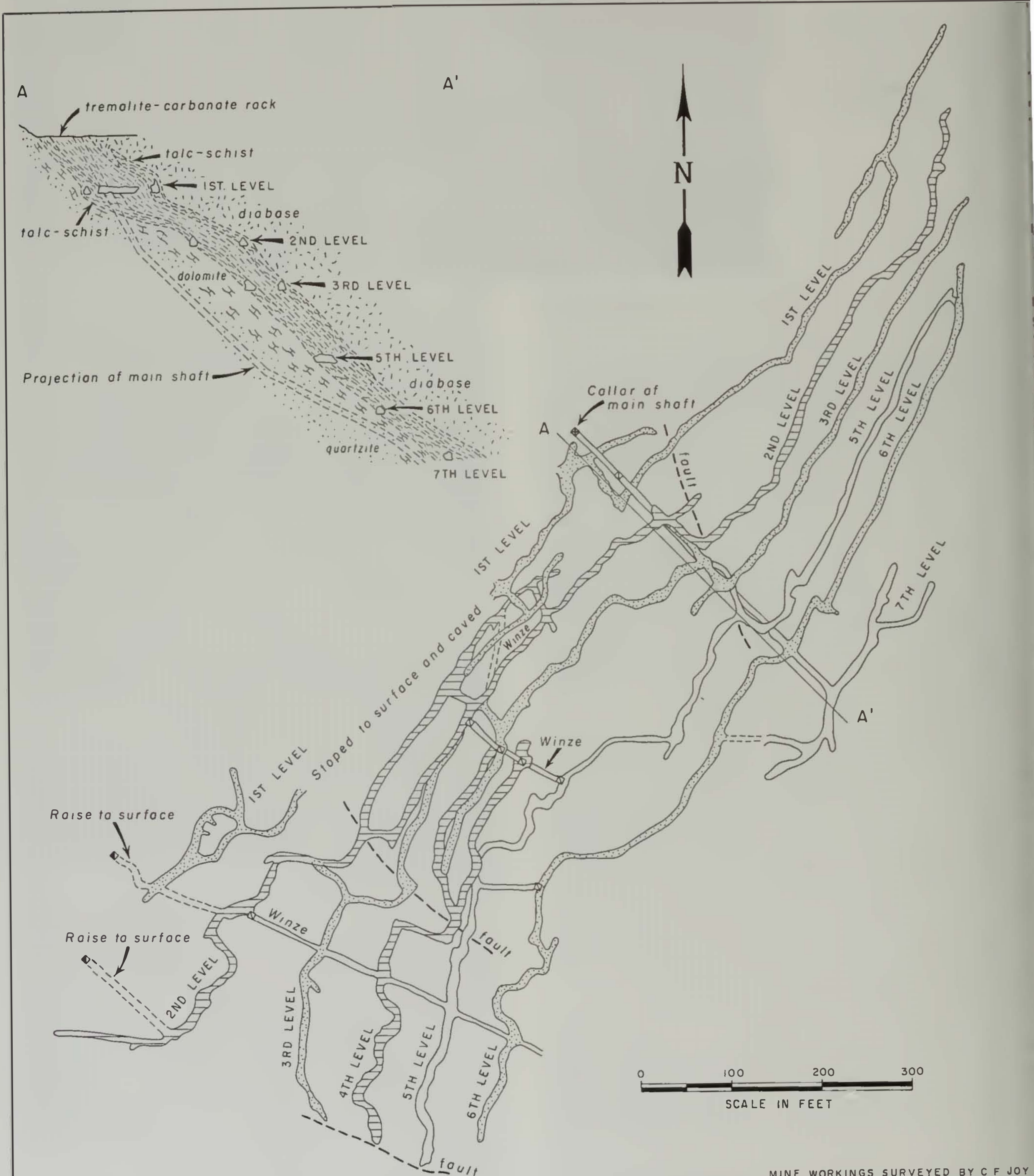

Figure 16. Plan of main levels, shafts, and winzes of Superior mine with geologic cross section. Workings have been driven almost entirely i layers of commercial talc. Between levels, layers have been extensively stoped.

'he material in the Number One vein has a dull, halky luster, whereas that of the Number Two vein as translucency and a porcellaneous sheen. Even in ome places outside of the three-layered part of the one, the lower part of the single layer has a chalky ppearance and the upper part is porcellaneous; in general, the single layer is predominantly chalky.

As they exist in 1961, the Superior mine workings consist of a main shaft inclined southeastward about 550 feet long and appended to seven levels that extend as drifts along the talc-bearing zone in both directions from the shaft and from cross-cuts joined to the shaft. All but a very small part of the drifting has been confined to mineable thicknesses of the talc layers, so that the accompanying map of the workings (fig. 16), in a general way, outlines the extent of the known concentration of commercial talc as well as the extent of the three-layered bulge.

The shaft is inclined 60° for 150 feet, 45° for 200 feet and 30° for the remaining 200 feet. The seven levels are at approximate slope distances of 75, 150, 210, 265, 335, 445, and 550 feet from the collar of the shaft. The fourth level does not connect directly with the shaft, but is joined to the other levels by means of a raise in the southwestern part of the deposit. Southwest of the shaft, in the area where, prior to 1952, almost all of the mining was done, all but the seventh level extend to points 700 to 800 feet from the shaft. The heading of each level is against the cross-fault already described. The seventh level has yet to reach the fault. On the first through fourth levels, where the three-layered bulge was encountered, drifts lie on both sides of the tremolitic layer.

The first underground working at the Superior mine was a drift (now the first level), started in 1940, with an adit portal about 540 feet southeast of the collar of the present shaft. Talc was stoped from this drift to the surface. The original shaft, inclined 45° southeastward, was sunk to the drift from a point about 250 feet northeast of the adit portal and was extended to the second level. In 1941, caving of the upper part of this shaft caused its abandonment and the opening of the present shaft, which also was extended to the second level.

The mining continued to center in the area southwest of the present shaft, as the deposit was believed to terminate against a cross-fault a few tens of feet northeast of the shaft. Levels three to six were driven from winzes at the southwest end of the workings and, at one time, talc from the lower levels was hoisted at three places before reaching the surface. As the northeastward continuity of the deposit was demonstrated, however, the shaft was deepened and joined to the lower levels thereby simplifying the mining procedure.

The northeastern part of the deposit, beyond the cross-fault, was discovered in 1953 by an extension of the second level and has continued at successively lower levels. Northeast of the shaft, the first, second, third, fifth and sixth levels extend for distances of 600 to 450 feet to points where the talc layer pinches. The alignment of these points plunges southward and has been presumed to represent the edge of the mineable body. The fourth level has not been driven northwest of the shaft. The seventh level extends for 160 feet in this direction and, at about 100 feet from the shaft, the talc body is cut off by a body of diabase the size and shape of which remains undetermined.

In 1960, most of the mineable talc from the fifth level to the surface remained in the form of pillars which the operators plan to remove as various parts of the mine eventually are abandoned. Stoping is continuing between the seventh and fifth levels, and deeper levels are planned.

Timmy deposit. The Timmy deposit, which has been only prospected, is exposed low on the east face of the Panamint Range about one mile south of the mouth of Galena Canyon. It is covered by two claims in sec. 17, T. 22 N., R. 1 E., S.B.M., and owned by Mr. Jack Madison of Shoshone, California.

At this locality, an elongate finger, composed of strata of the upper units of the Crystal Spring Formation, extends southward into a body of diabase. The finger, which is about 1400 feet long and 100 or more feet in average thickness, consists mostly of dolomite. It and the contained strata strike northward and are essentially horizontal, in some places dipping gently eastward, in others, gently westward.

For a distance of about 750 feet along the lower margin of the southern part of the finger are discontinuous exposures of white silicate rock composed mostly of the mineral talc. These exposures indicate the presence of two or more bodies of talcose silicate rock. Where exposed, the bodies are 8 feet or less thick. The largest indicated body appears to be at least 300 feet long and is 2 to 6 feet in exposed width. It consists mostly of white talc schist and contains limy veinlets. Other bodies, apparently smaller, are exposed high in the finger. The workings consist of a few shallow cuts and trenches, all exploratory.

Tough (A.C.) deposits. The Tough talc deposits are in a group of low hills which lie between the Alexander and Ibex Hills and are about four miles southwest of Tecopa. They are covered by several claims which are mostly or wholly in sec. 30, T. 20 N., R. 7 E., S.B.M. Although claims were first staked on these deposits in the 1940's or before, they were relocated in 1956 by Mrs. Glenn Thomas and R. J. Dickerson, both of Baker, California, but no talc had been shipped by early 1961.

The exposed bedrock, in the vicinity of these deposits, consists of a north-trending block, about 1¼ miles long, of Mesozoic (?) quartz monzonite. The northern part of this block underlies the lower slope of a north-trending ridge. An inclusion (?), composed mostly of diabase of the Crystal Spring Formation and about 500 feet in maximum exposed dimension, is bordered on the north, east, and south by quartz monzonite. Surrounding the block and flanking the mass of diabase on the west is a cover of Pliocene (?) sedimentary rocks composed of fanglomerate and bodies of monolithologic breccia, which consist variously of the quartz monzonite and units of the

Crystal Spring Formation. The bodies of breccia appear to have been shed from the ridge or other nearby exposures of bedrock.

The deposits consist of several separate bodies of talc within an area of half a square mile. At least three of them occur as septa in the inclusion of diabase. The others are bodies of monolithologic breccia within the section of Pliocene sedimentary rocks. None of the bodies can be traced along-strike for more than 150 feet, and the average thickness of each is within the range of two to six feet. They show various attitudes, but, in general, are steeply dipping. They are composed mostly of white silicated rock rich in the mineral talc and well to crudely foliated. Some of the rock is highly tremolitic, and some shows iron and/or manganese stains. The bodies have been explored by numerous shallow cuts and short adits and by two shafts, each about 15 feet deep.

Vulcan (Harry Adams) mine. The eastern part of the talc-bearing zone in Beck Canyon, northern Kingston Range, is covered by seven claims. Four of them are patented and owned by the D. F. McLaughlin Estate, 1911 Mills Tower Building, San Francisco. These are part of a large group that covers the Beck Iron deposits exposed on the north wall of the canyon. The other three are owned by Harry Adams, Box 322, Bloomington, California. All seven are leased by the Pomona Tile Manufacturing Company, 629 North La Brea Avenue, Los Angeles. This company has an option to purchase the last-mentioned three. The claims are in secs. 31 and 32 (projected), T. 20 N., R. 110 E., S.B.M.

The talc production has been confined to the Vulcan claim, one of the McLaughlin group, and began in 1938 when the claim was leased to Mr. Adams. The deposit was first worked by underground methods, mostly in the period 1939–42, and again in 1949. In 1952, while the claim was still under lease to Mr. Adams, open-pit mining began and has continued through 1960. The four claims of the McLaughlin Estate were leased in 1956 and the other three were leased in 1959. Through 1959 the mine had yielded about 9000 tons of commercial talc, of which about 3000 tons was mined by Mr. Adams. All of the talc produced by the present operator has been used in the manufacture of wall tile at the plant of the operator.

The Vulcan mine is near the northwest end of a talc-bearing zone that extends for about 1¾ miles low along the southwest wall of Beck Canyon. The zone lies beneath the lower diabase sill in the Crystal Spring Formation and is underlain by shaly and quartzitic strata of the lower part of the formation. The talc-bearing zone and the Crystal Spring units that border it strike about N. 55° W. and dip steeply to moderately northeastward. Here, as elsewhere, the talc-bearing zone is an alteration of the lowest strata of the carbonate member, but the rest of the carbonate member overlies the sill. The carbonate strata above the sill also are silicated, but less intensively than those beneath.

The trace of the thrust fault that separates the earlier Precambrian metamorphic rocks from the overlying units of the Crystal Spring Formation (see general description of talc in the Western Kingston Range) passes about 600 feet west of the Vulcan mine and here trends about N. 30° W. The fault dips northeastward at an undetermined angle. In the Vulcan mine area, it must cut out the talc-bearing zone at depth, probably within several hundred feet of the surface. The northern margin of the body of granitic rock that forms the main mass of Kingston Peak becomes progressively nearer the talc-bearing zone from west to east. It is within 300 feet of the eastern part of the zone, but does not cut it out.

In the Vulcan mine area, the talc-bearing zone is exposed at the northern end of a low, alluvium-flanked ridge. Here, the exposure of the zone is about 70-feet wide and 400 feet long, and the hanging wall and lateral extensions of the zone are hidden beneath alluvium. The zone dips about vertically.

All of the talc of commercial value has been mined within a 50-foot thickness of the zone. Here, elongate but irregular bodies of soft, white talc schist are interlayered with waste rock. The commercial material consists of 50 to 60 percent of the 50-foot width. Much of the talc is mottled with a brown stain but is said to "burn white" as a wall tile ingredient. Most of the waste rock is colored various shades of gray and green, is soft and chalky, and is reported by the operator to have a high content of alumina and alkalies.

During the period of underground mining the deposit was worked through a vertical shaft about 100 feet deep, joined to irregular level workings, all of which are now inaccessible. The former operator reports that water seepages in the lower part of the workings caused much difficulty.

The open pit, which was worked outward from the shaft opening, is about 200 feet long and 50 feet in average width. It consists of two benches, end to end, and the lower one to the northwest. The walls of the original bench have a maximum height of about 30 feet; the other bench, which was started in 1960, is about 30 feet lower.

The southeasterly extension of the talc-bearing zone from the Vulcan mine area is well exposed only in a few places. In general, it is hidden beneath alluvium and float. However, the alignment of the exposures and the presence of talc particles in the float along much of the northwestward projected trace of the zone indicate that it is continuous or nearly so to the crest of the drainage divide of Beck Canyon (see Kingston No. 8 deposit herein), a total distance of about 1½ miles.

In a few places, the zone has been exposed in shallow open pits and trenches. These exposures resemble those in the Vulcan workings, but, in them, the zone appears to be thinner and the bodies of commercial talc less continuous.

Western (Acme, Lindsay) mine. The Western mine, which has the most extensive workings and the longest operating history of the talc mines in the southern Death Valley-Kingston Range region, is in sec. 32 and 33, T. 20 N., R. 8 E., and secs. 4 and 5 (projected), T. 19 N., R. 8 E., S.B.M. The property consists of seven patented and four unpatented claims, in the orthwestern part of the Alexander Hills, and is owned nd operated by the Western Talc Company, 1901 East Slauson Avenue, Los Angeles. Through 1959, bout 310,000 tons of talc had been mined.

The talc bodies at this locality were being worked s early as 1912 and may have been opened one or two years before then. In 1912, the property was worked by the Independent Sewer Pipe Company, but this operator was out of business by 1914. During the period 1914–22, production was recorded successively under he following company names: Tropico Tile and Terra Cotta Company, Pacific Talc and Terra Cotta Company, Pacific Minerals and Chemical Company, and Tropico Potteries Company. All of these names probably refer to essentially the same business organization of which a Mr. A. Lindsay was president. Mr. Lindsay also owned the active claims and directed the operation which was then known as the Acme or Lindsay mine.

In 1923, with the failure of Mr. Lindsay's venture, the property was leased by a former business associate of his—a Mr. Martin, who organized the Master Minerals Corporation. This corporation later became the Martin Minerals Company. In 1923, also, the Western Talc and Magnesite Company was organized and began to produce talc from the Snow Goose claims, which covered a hitherto undeveloped segment of the deposit. In 1928, this company, under the presidency of Mr. Fred Savell, acquired the holdings of the Martin Minerals Company and applied the name Western Talc Company to the combined operations. Since then, all of the workings on both of the properties have been referred to collectively as the Western mine, and Mr. Savell continues as president of the company.

The claims of the Western mine cover all of the talc-bearing exposures in the northwest quarter of the Alexander Hills and in the low area to the northwest of the hills. Here, as at numerous other localities in the surrounding region, the talc-bearing zone has formed as an alteration of cherty dolomite at the base of the Crystal Spring Formation. A diabase sill forms the footwall of the talc bodies through most of the mine area, but in the southern part, elongate bodies of green alteration rock locally separate the white rock from the diabase.

Most of the claims are distributed along two north-striking segments of the same alteration zone. These segments have been displaced along a northeast-striking fault, the northern end of one segment being about 4000 feet northeast of the southern end of the other. The two have a combined length of several thousand feet and appear to be the two largest of the essentially intact bodies of commercial talc in the southern Death Valley-Kingston Range region.

The longer and more easterly segment is almost continuously exposed for a distance of about one mile, low along the west slope of the hills. To the south, it projects beneath alluvium and probably extends for an additional 2000 feet to include the previously described Acme deposit. For convenience, this segment, where exposed on the Western mine property, will be referred to here as the "Lindsay body", as this was the site of Mr. Lindsay's operations. The other segment is

Photo 20. View northward along Lindsay talc body at Western mine. Cherty dolomite forms upper part of main ridge, is overlain by limestone on right slope, and underlain by talc-bearing zone (white band). Diabase sill (dark band) forms most of lower part of ridge and is exposed in foreground. Number 3 shaft is in right foreground, and Number 2 shaft is above building in mid-distance.

in an area of low relief west and northwest of the Lindsay body. It appears to be at least 3400 feet in overall length, and generally is known as the "Number 5" body. It lies southwest of the area of plate 4.

Other talc bodies occur along a northwest-trending fault which is exposed in the area west of the southern part of the Lindsay body (pl. 4). These bodies are discontinuous, contain highly crushed talc, and remain unmined.

In most of the observed exposures of the two main segments, the zone of alteration is 30 to 100 feet thick and consists chiefly of saleable material. Each has been mined down-dip to a maximum depth of about 350 feet, and in general, each dips moderately eastward. In detail, however, both segments show marked irregularities most of which are attributable to one or more of the following features: (1) rolls in the footwall, (2) cross-faults, (3) slippages parallel with the talc bodies, and (4) small bodies of diabase that penetrate the talc-bearing zone. In a few places, the footwall is overturned steeply westward, and in others it is nearly horizontal. The apparent horizontal displacement of the cross-faults are rarely more than 30 feet.

The talc-bearing zone contains two principal types of commercial talc: (1) laminated tremolite rock (generally referred to as "hard talc") which consistently occurs in the lower part of the zone to form a layer, 10 to 20 feet thick, adjacent to the diabase footwall, and (2) talc schist (generally referred to as "soft talc") most of which is confined to the upper part of the zone, but which, in some places, forms the full

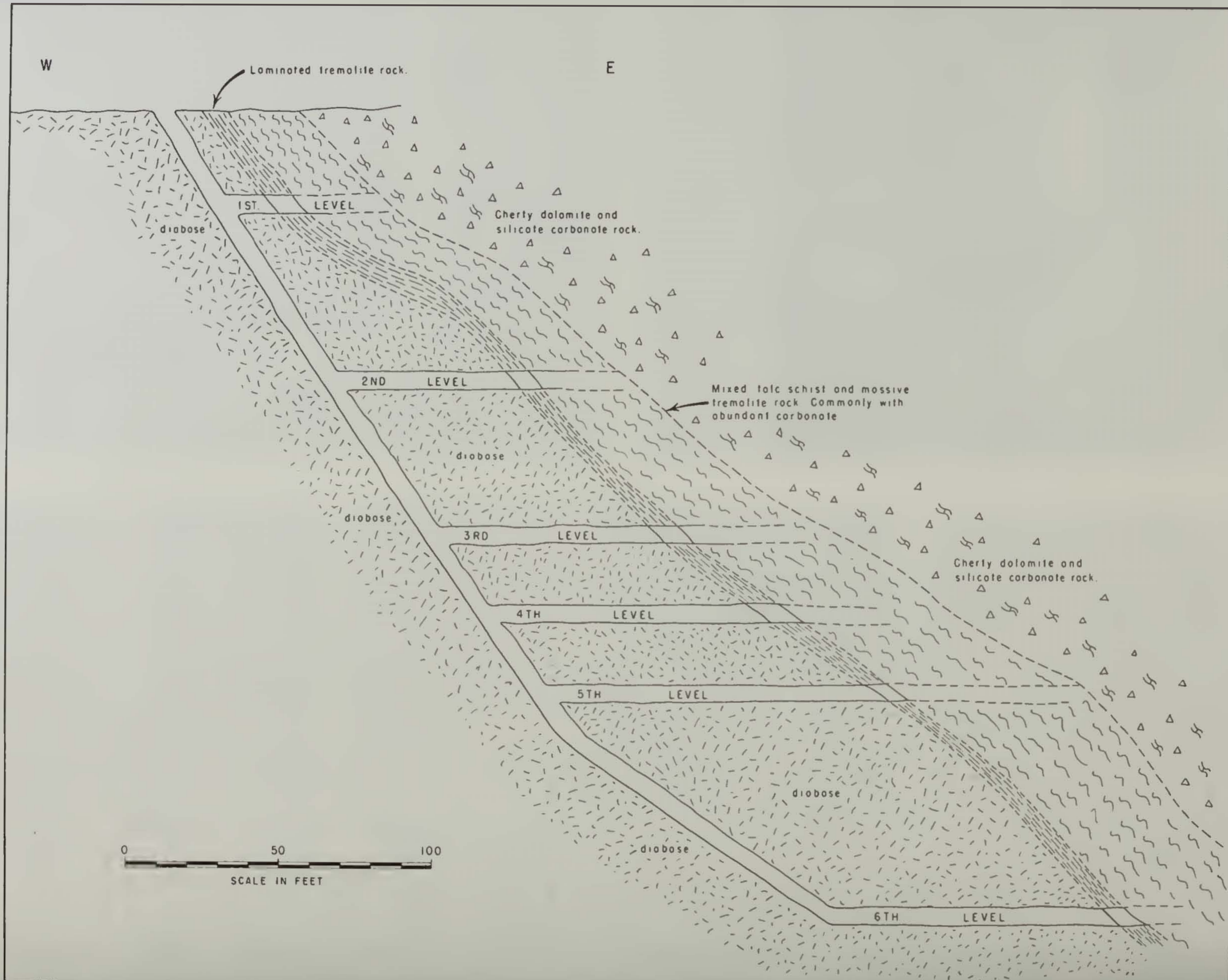

Figure 17. Geologic cross section through No. 5 workings of Western

thickness of the zone. Commonly mixed with the talc schist is a blocky tremolite-carbonate rock known as "tuff talc."

A layer, several feet thick, of brown alteration rock ordinarily forms the upper part of the zone, thereby separating talc schist from unaltered cherty dolomite. Comparably thick bodies of brown rock also occur as irregular fingers that extend at low angles into the talc schist, and as layers and irregular masses within the talc-bearing zone. The brown rock is everywhere in sharp contact with the talc schist, but has a gradational contact with the overlying cherty dolomite.

The bodies of talc schist commonly contain concentrations of carbonate material (predominently dolomite). In some places, particularly in the Number 5 body, such concentrations appear to be relict strata now partly altered to talc. The lower margins of some of the masses of brown alteration rock are discontinuously bordered by masses of nearly pure dolomite as much as one foot thick. Small veinlets of silica are sparsely and irregularly distributed throughout the talc-bearing zone but are most abundant in the upper parts of the talc schist bodies.

The Lindsay body has been worked through several adits and five shafts, inclined northeastward to east-northeastward at angles of 50° to 70° and all within an interval of 4500 feet. The level workings, appended to all but the most southerly shaft, now are largely inaccessible, but mine records indicate that they total several miles in length and extend almost continuously through the 4500-foot interval. From north to south, the shafts have been designated as Numbers 4, 1, 2, 3, and 6, the numerical order indicating the sequence in which they were opened. These are spaced at intervals of about 1350, 1300, 950, and 800 feet, and available data indicates that they are about 150, 350, 190, and 150 feet long respectively.

In general practice, the shafts, including the Number 5 shaft on the Number 5 body, have been collared at the footwall of the alteration zone and have been sunk at angles steeper than the average dip of the footwall. As the shafts have been deepened, therefore, successively longer cross-cuts have been driven through diabase to the talc bodies. These levels have been spaced at intervals of 50 to 100 feet. Shafts 1 through 4 have 5, 3, 3, and 2 levels respectively. Most of the talc removed from the Lindsay body was mined from the irregular drifts as they were advanced on the main levels and sublevels and from irregular raises. Stoping was unsystematic, and rarely was the full width of the talc body removed. Large tonnages of commercial talc remain in the Lindsay body, therefore, but, if the workings should be reopened, the talc will be removed with much more difficulty and more expensively than the earlier production.

The Number 6 workings, the most southerly, most recently developed, and most accessible of those along the Lindsay body, consist of an inclined shaft, about 150 feet in slope-length, with inextensive level workings at intervals of about 40, 90, and 150 feet. In the area of these workings, the surface exposures of the Western deposit show a lower part, 15 to 25 feet thick, composed of laminated tremolite rock and an upper part, of comparable or greater thickness, composed of white talc schist mixed with grayish green limy waste rock. Where exposed underground, the material of commercial interest, lying next to the diabase footwall, is generally 4 to 10 feet thick and consists of mixed tremolitic rock and talc schist. In the surface exposures near the Number 6 workings the alteration body dips 30° to 35° eastward, but underground, the dip averages about 50°.

Each of the three levels consists of a short cross-cut from the shaft to the body and a drift extending both north and south. From the first to third level, the northern parts of the drifts are about 45, 10, and 55 feet long and the southern parts are about 75, 90, and 30 feet respectively.

The Number 5 shaft was begun in late 1950. Since then, nearly all of the Western mine production has been obtained from the level workings and stopes appended to the shaft. From the most northerly of the underground workings southward, the Number 5 body has been traced continuously along-strike for about 2200 feet. Here, the body strikes northward and shows a generally moderate eastward dip. Although the northern part of the body is largely hidden beneath alluvium, exposures of talc that appear to be a continuation of the body suggest the 3400-foot total length previously indicated.

Where observed, this body of silicated rock averages about 50 feet in thickness and is typical of the zone in that it consists of a lower layer of laminated tremolite rock and an upper layer composed of mixed talc and carbonate material. The two layers ordinarily are separated by a layer of pale gray to brown, carbonate-rich waste rock.

The underground workings center about an inclined shaft that trends N. 15° to 25° E. and is 350 feet long. It slopes 59° to 55° to 240-foot and 30° to 35° to the bottom (fig. 17). Six levels extend from the shaft at slope distances of 40, 108, 168, 198, 230, and 350 feet. At each level, a cross-cut extends eastward to the talc body and drifts trend north and south in the body. Late in 1960, the drifts on the first to sixth levels extended southward about 390, 600, 840, 50, 720, and 680 feet and northward about 130, 1200, 480, 50, 400, and 200 feet respectively. Neither the northern nor the southern termination of the body has been encountered underground.

Most of the drifting has been done along the footwall of the body and within the layer of laminated tremolite rock, although drifts also are common in the upper layer. Until the mid-1950's the drifting had been very irregular in plan. Most of the talc had been mined from a tortuous system of raises, small stopes and sublevels and with a minimum of timbering. In recent years a more systematic method, employing wide, straight drifts and large, square-set stopes has been employed. Most of the square-set timbering to date has been done between the fifth and third levels and from 250 to 500 feet on both sides of the shaft.

The layer, next to the footwall, of laminated tremolite rock persists throughout all of the workings except in the northern parts of the fifth and sixth levels. In thickness, it averaged 12 to 15 feet and shows a maximum of about 25 feet. The overlying layer of limy waste rock is ordinarily 5 to 8 feet thick, but locally is much thinner or missing altogether.

The upper and talcose part of the body pinches and swells from a few feet to as much as 75 feet in thickness and averages about 35 feet. In some places, particularly in the northern part of the Number 5 level, the upper part of the body consists mostly of white talc schist, but in general it is sufficiently rich in gray carbonate material to be blocky and bluish gray in color. Both the schistose and blocky rocks have been extensively mined as commercial talc. Abundant through much of the upper layer are "boulders", lenses, and tongues of brown alteration rock. They constitute more than half the width of the layer in parts of the north drifts on the fifth and sixth levels where they have hindered mining and exploration.

White Cap mine. The White Cap mine is on one of the six claims of the Superior-White Cap group and has been worked in connection with the operation of the Superior mine, but on a much smaller scale. The claims are owned by the Southern California Minerals Company, 320 South Mission Road, Los Angeles. They lie athwart the Saratoga Hills, which form part of the east margin of southern Death Valley. The claims are in secs. 25 and 26, T. 19 N., R. 5 E., S.B.M. The White Cap mine was operated only during the period 1947–1951 and yielded 6315 tons of commercial talc.

The White Cap deposit is about 1600 feet southwest of the Superior deposit. All of the output of the White Cap mine has been obtained from a single body within a much more extensive zone of silicated rock. The zone is exposed low along the northwest slope of a small ridge and probably averages 40 feet or more in width. The zone appears to be about 1000 feet long, but it may be broken in half by a cross-fault beneath alluvium which covers the middle segment of the zone. The projections of the zone beneath the cover suggest an apparent horizontal displacement of about 200 feet, the northeast side having moved southeastward. Both segments of the zone strike northwestward and dip about 45° southeastward.

The northeastern part of the zone, like the zone at the Superior mine, lies beneath the lower margin of the lower diabase sill in the Crystal Spring Formation. Between the two mine areas, this part of the formation, although generally barren, shows several exposures of white silicated rock. None of the bodies thus indicated has appeared large enough to be mined. At the southwestern end of the White Cap zone, a projection of the sill extends beneath the zone, so that the zone forms a finger that tapers southwestward and terminates in diabase.

Mining to date has been confined to a body in the lower part of this finger. The body is a lens, the footwall of which is diabase and the hanging wall is subcommercial silicated rock and, in the southwestern part of the finger, diabase. The body consists of material that ranges from friable talc-rich schist to highly tremolitic rock, both massive and thinly laminated. The body is highly fractured and sheared; in general, the talcose rock is more abundant near the footwa whereas most of the tremolitic rock is confined to th hanging wall part. The body can be traced alon strike on the surface for about 400 feet, but has bee mined underground for a maximum strike length o about 200 feet and down-dip for about 200 fee Where penetrated by the workings, the body ranges i thickness from a few inches to about 15 feet an averages about 8 feet thick. The level workings hav been driven to places where the talc body narrows t thicknesses of three feet or less.

The White Cap mine workings consist of an in clined shaft about 200 feet long and joined to drif at slope distances of 50, 100, 130, 160, and 200 fee The shaft steepens from an average slope of about 35 in its upper half to 65° at the bottom. The drift at th 50-foot level extends 60 feet to the northeast and 6 feet to the southwest of the shaft. The drift at th 100-foot level extends 50 feet eastward and 150 fe southwestward. The 130-foot and the 160-foot lev drifts extend 60 feet northeastward and 50 feet south westward respectively. At the 200-foot level, a dri extends about 100 feet southwest and 100 feet north east of the shaft.

The northeasterly segment of the alteration zon which is poorly exposed, has been explored by mean of bulldozer cuts and several shallow pits, but th silicated rock uncovered is not of present commerci interest to the operators.

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