

Table 1. MEAN DIRECTIONS OF MAGNETIZATION AND POLE POSITIONS

Geological unit	N	n	s	Mean direction of magnetization				Pole position				Divergences	
				D	I	R	$\alpha$	Latitude	Longitude	$\delta\psi$	$\delta\chi$	$\Delta F$	$\Delta P$
Dolerite sills	8	11	20	262	-70	7.889	7	51° S.	132° W.	10	12	23	21
Basic dykes in grey granite	10	14	31	237	-56	9.832	7	29° S.	149° W.	7	10	32	38

N denotes the number of sites, n is the number of samples collected and s is the number of specimens cut from these samples. D and I are the declination and inclination of the resultant direction of magnetization computed by giving each site unit weight. R is the length of the resultant,  $\alpha$  is the error of the mean at  $P = 0.05$  (Fisher, ref. 4), and  $\Delta F$  and  $\Delta P$  are the divergences of the mean direction from the present Earth's field (155°, -83°) and from the dipole field (0°, -84°) respectively. The pole positions in the southern hemisphere are specified by latitude and longitude and the errors  $\delta\psi$  and  $\delta\chi$  are in the direction of and at right-angles to the co-latitude, respectively.

long. 107° W.), by Turnbull<sup>2</sup> from the Cainozoic volcanics of Cape Hallett (lat. 81° S., long. 94° E.), dolerite sills of the Ferrar Glacier (lat. 58° S., long. 142° W.) and from the Beacon Sandstone (lat. 53° S., long. 151° W.), and by Blundell and Stephenson<sup>3</sup> from some dolerites from Theron Mountains and Whichaway Nunataks (lat. 54° S., long. 136° W.). These poles, together with those calculated from our results, are plotted in Fig. 1. The results from the dolerites are in good agreement. Turnbull is of the opinion that the Beacon Sandstone he sampled may have been reheated by the dolerite, which thus accounts for the agreement of the result from the Sandstone with the dolerites.

The precise geological age of these rock formations is not known. The basement dykes could be Palaeozoic, the Beacon Sandstones are probably for the most part Upper Palaeozoic or Early Mesozoic, and the dolerites are very likely to be Mesozoic in age. However, except for 4C, about the age of which little can be said, the relative age sequence is almost certainly that given in Fig. 1. The following general points may therefore be made.

(1) The divergence of the palaeomagnetic pole from the present geographical pole increases with geological age. In geological recent times it is in the vicinity of the present pole and in the Pre-Cambrian it is near the present-day equator (see ref. 1 for discussion of the latter point).

(2) The poles have characteristic longitudes between 100° and 150° W. In these two features the

results are similar to the pole paths obtained from Europe, North America, India and Australia.

(3) However, the longitudes differ very greatly (in some cases by 100° or more) from the longitudes of the poles obtained from these four regions. This result emphasizes for yet another continent the divergence that occurs between results from different continents for periods prior to the Tertiary.

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<sup>1</sup> Nagata, T., and Shimizu, Y., *Nature*, **184**, 1472 (1959).

<sup>2</sup> Turnbull, G., *Arctic*, **12**, 151 (1959).

<sup>3</sup> Blundell, D. J., and Stephenson, P. J., *Nature*, **184**, 1860 (1959).

<sup>4</sup> Fisher, R. A., *Proc. Roy. Soc., A*, **217**, 295 (1953).

### Infra-Red Determination of the Kaolin Group Minerals

By infra-red absorption analysis, it is possible to make a semi-quantitative estimation of the kaolin minerals. In contrast to X-ray diffraction, the infra-red spectrum of halloysite is as clearly defined as those of kaolinite and dickite, and the content of these three minerals in mixtures can be determined by a ratio between the depths of their hydroxyl absorptions. The peaks at  $2.70\mu$  (A) and  $2.75\mu$  (B) are common to all three minerals, and a peak depth ratio A/B of 1.2-1.5 is characteristic of kaolinite, with a ratio A/B of 0.8-0.9 characterizing halloysite. Values of 0.6-0.8 are typical of dickite. If the depth of the band due to physically adsorbed water at  $2.9\mu$  (C) is plotted as the abscissa with A/B as the ordinate, the three minerals fall into separate areas.

Examination of the spectra due to Si-O and Al-Si-O between  $8.9$  and  $10.1\mu$  show a diagnostic pair of doublets. The doublet at  $10.7\mu$  (D) and  $11.0\mu$  (E) is typical of the Al-O-OH bonding of kaolinite and dickite, although only the single peak at  $11.0\mu$  appears for halloysite. An inspection of the A/B ratio and the presence, or absence, of absorption (D) enables a unique distinction to be made between the three minerals. The A/B ratio remains constant during dehydration over several hours up to  $450^\circ\text{C}$ .

The absorption at  $2.70\mu$  (A) is found only in the kaolin group and in such simple structures as brucite. It is due to oxygen-hydrogen stretching frequencies associated with the hydroxyl ions, the oxygen and hydrogen atoms being in two symmetrical layers in

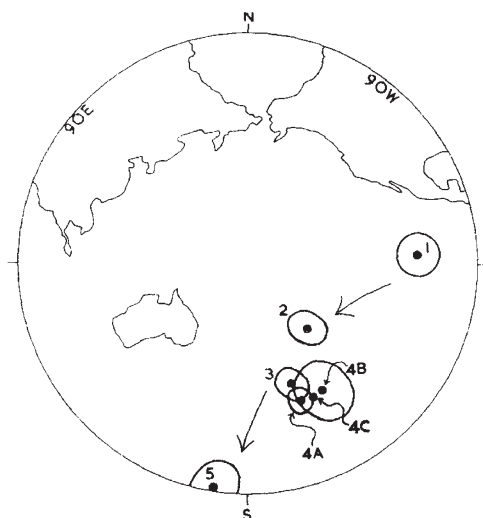


Fig. 1. Pole positions from Antarctica. The pole positions are numbered as follows: 1, Ongul Island gneiss; 2, basement dykes; 3, Beacon Sandstone; 4A, dolerite sills, Ferrar Glacier; 4B, dolerite sheets of Wright Valley; 4C, Theron and Whichaway dolerites; 5, Hallett Cove volcanics. The projection is equatorial stereographic.

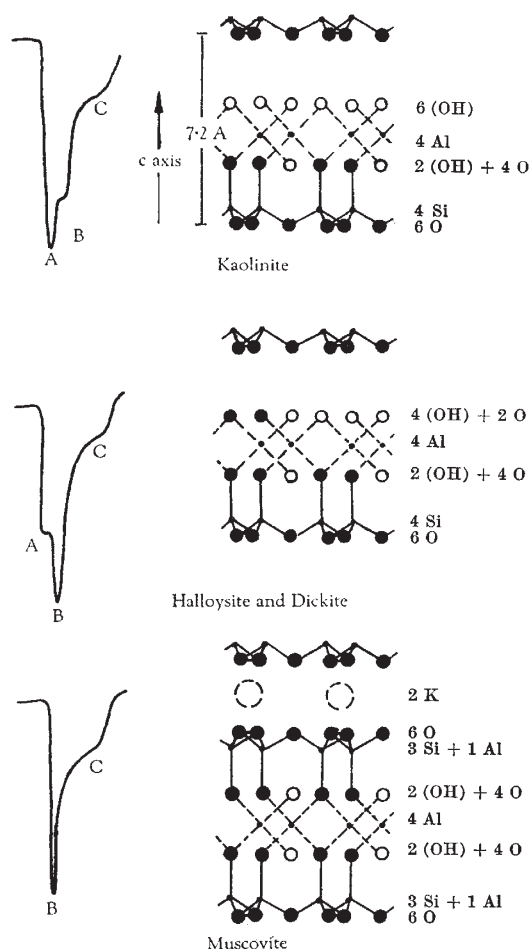


Fig. 1. Suggested oxygen-hydroxyl configuration for halloysite and dickite as compared with kaolinite and muscovite. Hydroxyl portions of their infra-red curves appear to the left of each structure

the brucite crystal. The  $2.75\mu$  (B) absorption is common to all micas and three-layer minerals, which differ from kaolinite in that their upper layer of oxygen-hydroxyls is only one-third hydroxyl, two-thirds oxygen.

A modification of the general kaolinite structure is proposed to explain the similarity in A/B ratio in halloysite and dickite as contrasted to that of kaolinite. The frequency of hydroxyls in the upper oxygen-hydroxyl level in the kaolinite structure must vary between 3/3 (as in kaolinite) and 1/3 (as in the micas, when both upper and lower levels of the octahedral layer become symmetrical) (Fig. 1). Micas thus have a single (B) hydroxyl absorption. Kaolinite itself shows a full upper level of (A) type and full lower level of (B) type. Halloysite and dickite must lie at an intermediate value where 2/3 of the upper level are hydroxyls. This would decrease the strength of the (A) type absorption and increase the strength of the (B) type absorption, lowering the A/B ratio.

Aluminium-silicon substitution (Y number) in the basal, tetrahedrally co-ordinated levels of kaolinite,

as proposed by Bates<sup>1</sup>, should be very easy to determine in the same manner as used in the chlorite and other mica studies<sup>2</sup>.

A more complete study on this subject will be presented at the forthcoming Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy in March 1960.

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<sup>1</sup> Bates, T., and Comer, J. J., *Clays and Clay Minerals*, Proc. Sixth Nat. Clay Conf., Nat. Acad. Sci.-Nat. Res. Council (1958).

<sup>2</sup> Tuddenham, W. M., and Lyon, R. J. P., *Anal. Chem.*, **31**, 377 (1959).

### Sea-Level Fluctuations during the Past Four Thousand Years

STUDY of constructional details of a chenier plain along the coast of the Firth of Thames, New Zealand, together with radiocarbon dating of seven shell samples, has enabled the production of Fig. 1. Criteria used in interpreting the past sea-levels were (a) storm ridges, (b) high-spring-tide wash benches and (c) tidal stream flats. Often all three criteria could be used to determine one sea-level. Periods of sea-level highs correlate well with periods of transgression recorded along the European coast<sup>1-3</sup>.

Tectonic movement, compaction and other causes could have led to misleading results; but their effects are considered small. Thus neglecting the minor fluctuations shown in Fig. 1, sea-level fell 7 ft. from 2000 B.C. to about the beginning of the Christian era and has remained relatively stable since. The present rise of sea-level is locally 8-9 in. per century and may well be only another minor fluctuation in an otherwise stable sea.

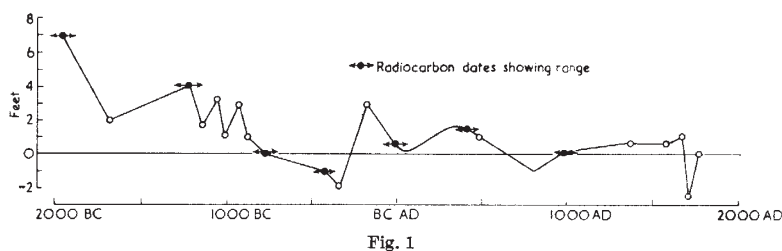


Fig. 1

Details will be published shortly in the *New Zealand Journal of Geology and Geophysics*.

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<sup>1</sup> Bakker, J. P., *Geologie en Mijnbouw*, **16**, 232 (1954).

<sup>2</sup> Bennema, J., *Geologie en Mijnbouw*, **16**, 254 (1954).

<sup>3</sup> Tavernier, R., and Moormann, F., *Geologie en Mijnbouw*, **16**, 201 (1954).