evidence against the theory of M. Vatonne as to the dunes having been formed *in situ.*

Although now mainly waterless, the Sahara possesses the skeleton *of* a regular river-system. From the north side of the Atakor-'n- Ahaggar, through which runs the “ water-parting ” between the basins of the Mediterranean and Atlantic, begins Wadi Igharghar, which, running northwards between the Tasili plateau and the Irawen mountains, appears to lose itself in the sands of the Eastern Erg, but can be traced northwards for hundreds of miles. Its bed contains rolled fragments of lava and freshwater shells *(Cyrena* and *Planorbis.* In a line almost parallel to Wadi Igharghar, Wadi Mya descends from the plateau of Tademayt, and shows the importance of its ancient current by deep erosion of the Cretaceous rocks, in which a large number of left-hand tributaries have also left their mark. The streams flowing south from the Atlas, which seem to be absorbed in the sands of the desert, evidently find a series of underground reservoirs or basins capable of being tapped by artesian wells over very extensive areas. As Olympiodorus (quoted by Photius) mentions that the inhabitants of the Sahara used to make excava­tions from 100 to 120 ft. deep, out of which jets of pure water rose in columns, it is clear that this state of matters is (historically) of ancient date. Since 1856 French engineers have carried on a series of borings which have resulted in the fertilizing of extensive tracts. In Wadi Righ (otherwise Rhir), which runs for 80 m. towards the south-west of the Shat Melrir (department of Constantine, Algeria), the water-bearing stratum is among permeable sands, which are covered to a depth of 200 ft. by impermeable marls, by which the water is kept under pressure. In this valley many artesian wells have been sunk by the French. Connexions probably exist with subterranean water-supplies in the mountains to the north. That the water in the artesian reservoirs is kept aerated is shown by the existence below ground of fishes, crabs and freshwater molluscs, all of which were ejected by the well called Mezer in Wadi Righ. Further west the Wadis Zusfana and Ghir unite to form the Saura, known in Tuat as the Messaud. These rivers still carry water as far as the northern part of Tuat; thence the course of the Messaud was, apparently, S.W. to the eastern Juf. There are also well- marked river-beds in the central (Sahara. The Wadi Telemsi, rising in Adrar, of the Iforas, apparently joined the Niger near Gao, while the Wadi Taffassassent, which rose in the Ahaggar mountains, is believed to have been the ancient upper course of the lower Niger. The oases are also proofs of the presence of a steady supply of underground moisture, for vegetation under the Saharan climate (beyond the few plants specially adapted to desert conditions) is

exceptionally thirsty.

The existence of these wadis or river-beds is a factor in the con- sideration of the cause of the desert nature of the country. In all parts of the Sahara there is evidence of denudation carried out on a scale of unusual magnitude. The present surface of the desert has been exposed to the protracted wear and tear of the elements. But to determine the exact method by which the elements have done their work has hitherto proved beyond the power of science. The theory of *submarine* denudation was accepted by many scientists of the mid-Victorian era. The sand-dunes, the salt efflorescence and deposits, and the local occurrence of certain modern marine molluscs all go to help the hypothesis of a diluvial sea. Nor is evidence lacking that in cretaceous times portions of the Sahara were covered by the sea. Colonel P. L. Monteil brought home (1892) a fossil sea-urchin from Bilma. In 1902 at Tamaske, some 250 m. W. of Zinder, and a little north of Sokoto, a nautilus and four sea-urchins (fossils) were found by Captain Gaden in a limestone bed. Similar fossils occur in the region between Zinder and Air, and others of the same age have been found near Dakar. Basing his conclusions on these and other facts, de Lapparent held that an arm of the sea extended inland from the Atlantic to the eastern Sahara. This sea was bounded on the north and east by the mountains of Air, Ahaggar, the Asjer Tasili, &c. An extensive acquaintance with Saharan characteristics shows, however, that a sea for the Sahara as a whole is impossible. Henri Schirmer, who in 1893 published an admirable summary of Saharan geography up to that date, argued that the desert nature of the Sahara is due to forces which have been at work for ages, although, as in all deserts, the dryness is probably progressively increasing. The primary cause is to be sought in the existing distribution of land and sea, the great land mass of North Africa causing an outflow of air in all directions (and consequent absence of rain) in winter, and an in- draught in summer, when the surface is intensely heated and the relative humidity of the atmosphere becomes so small that con­densation is all but impossible. The vicinity of the comparatively cool Mediterranean in the north accentuates the force of the winds from that direction, which, blowing towards a lower latitude, are in their very nature dry winds. The influence of mountain ranges, such as the Atlas, round the border of the desert, is thus but a sub­ordinate cause of the latter’s dryness, which would probably be little diminished did the Atlas not exist. This dryness reacts again on the temperature conditions of the Sahara, accentuating both the daily and annual variation. The intense heat of the day is compensated by the cold of the nights, so that the mean annual temperature is not excessive. The difference between the mean temperature of

the hottest and coldest month has been found to be as high as 45° F.,and the extreme range at least 90° F., maxima of 112° and over having been frequently observed. As a result of the extreme dryness of the air, evaporation is excessive, and, being greater than the precipitation, involves a progressive desiccation of the Sahara. The surface of the rocks, heated by the sun and suddenly chilled by rapid radiation at night, gets fractured and crumbled; elsewhere the cliffs have been scored and the sand thus formed is at once turned by the wind into an active instrument of abrasion. In many places it has planed the flat rocks of the hammada as smooth as ice. Elsewhere it has scored the vertical faces of the cliffs with curious imitations of glacial striation, and helped to undercut the pillar or table-like eminences—remains of former more extensive plateaus—which, under the name *gur,* arc among the most familiar products of Saharan erosion. The softer quartz rocks of the Quaternary and Cretaceous series have been made to yield the sand which, drifted and sifted by the winds, has taken on the form of dunes. The slighest breeze is enough to make the surface “ smoke ” with dust; and at times the weird singing of the sands, waxing louder and louder, tells the scientific traveller that the motion is not confined to the superficial particles. The dry wind of the Sahara is known in southern Europe as the Sirocco. It brings with it clouds of fine red dust, as noted long since by Idrisi, the Arabian geographer. Dr Theobald Fischer and Dr Oscar Fraas agree in believing that the desiccation has markedly increased in historic times. Evidence derived from ancient monuments combined with the statements of Herodotus and Pliny arc held to prove that the elephant, the rhino­ceros, and the crocodile existed in North African regions where the environment is now utterly alien, and on the other hand that the camel is a late introduction.

Any attempt to improve the climatic conditions of the Sahara as a whole can hardly meet with success when the causes of its desiccation are considered. Much may, however, be done to modify local conditions, and fairly satisfactory results have been obtained in the direction of fixing the dunes and covering them with a growth of vegetation. Experiments carried out by the French at Ain Sefra, on the northern border of the desert, have shown that by protecting the sand from the action of the wind by a litter of alfa grass, time is given for the establishment of suitable trees, which include the tamarisk, acacia, eucalyptus, prickly pear, peach and aspen poplar, the last-named having proved the most capable of all of resisting the desert conditions. Such planting operations can only be carried out in favourable localities, such as valleys in which a certain amount of water is available. Wide areas like the arid stony plateaus (hammada) must be abandoned as hopeless.

As already stated, the popular conception of the Sahara as a sand desert is erroneous. It is really a stony, wind-swept waste with much bare rock visible, the actual area of pure sand forming a relatively small portion. A broad belt of Archaean rocks extends throughout the desert, appearing at intervals in the form of hills and plateaus from beneath the superficial sands and Quaternary deposits. Examples are the granite of Air and the gneiss and mica-schists of this massif and of the Ahaggar plateau. Flanking this zone are immense tracts occupied by rocks of Devonian and Carboniferous ages, from which characteristic marine fossils have been obtained at the springs of El Hassi and between Wad Draa and the dunes ol Igidi. *Productus africanus* is a common fossil of the Carboniferous rocks. At the close of the Carboniferous period it has been generally considered that the southern and central Sahara became dry land and has remained so up to the present day. Marine fossils of Cretaceous age have, however, been found within recent years in the central regions; while Eocene echinoids have been obtained near Sokoto *(Geol. Mag.,* 1904). During Lower Cretaceous times the Mediterranean covered the Algerian and Tripolitan Sahara and the northern portion of the eastern desert; the extensive development of the Cretaceous system being one of the most striking features of Saharan geology. At the close of the Cretaceous period the Tripolitan Sahara completely emerged, but parts of the Tunisian and Algerian Sahara seem to have remained below sea-level until the end of the Lower Eocene. Only on the extreme borders of the desert, however, do tertiary for- mations play any prominent part. During the Quaternary period the Sahara possessed a moister climate than the present. This is shown by the numerous water-cut valleys, now dry, and by the remains of hippopotamus in the Quaternary deposits.

The idea so long held that the Sahara represented the recently dried-up bed of an extension of the Mediterranean has been disproved by the investigations of French geologists. The sand is mainly derived from the wide expanse of Cretaceous sandstones, which become rapidly disintegrated by the contraction caused by the wide range of temperature between day and night. The loose sands of the Quaternary deposits also furnish abundant material. The true dune sand is remarkable for the uniformity of its composition and the geometrical regularity of its grains, which measure less than ∙03937 in. While individually these appear transparent or reddish yellow (from the presence of iron), they have in the mass a rich golden hue. According to Tissandier animal organisms, such as the microscopic shells of Rhizopoda, abundant in sea-sand, arc strikingly absent.

Botanically the Sahara is the meeting-ground of representatives