The occurrence of potassium nitrate near Goyder's Pass, McDonnell Ranges, Central Australia.

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ABOUT two years ago an aboriginal at Alice Springs in Central Australia reported that at a spot near the western extremity of the McDonnell Ranges the earth, if thrown upon a camp fire, did not extinguish the flames, but on the contrary increased the blaze. To those who heard the story this suggested the occurrence of oil, and it was decided to make some investigations. With the assistance of the native the spot was visited and located on the map. A sample of a white substance, which stimulated the burning of faggots, was forwarded to Adelaide University for examination and proved to be potassium nitrate. As a consequence Mr. C. T. Madigan, B.E., M.A., and myself paid a visit of inspection to the locality.

Location.—The discovery is situated about 120 miles due west of Alice Springs and a little to the south of Mt. Zeil. Its position is more definitely fixed on the map by stating that it lies some three or four miles to the north-east of Goyder's Pass. It is, therefore, in what is known as Mareenie Valley, located in undulating country with high ranges to the north and to the south.

The deposit of potassium nitrate is in the higher portion of a small hill rising about 70 feet above a dry gum-creek which extends along its western side, distant a quarter of a mile. This rise is one of several situated along the outcrop of a belt of dolomitic limestone, which latter trends in a nearly north and south direction.

The immediate vicinity is covered with porcupine grass, though the country thereabouts is principally occupied by mulga scrub. Timber of any size, such as *Eucalyptus rostrata,* appears only along the gum-creek and other dry watercourses of the neighbourhood. The latter carry surface water only during and immediately after

a fall of rain, a contingency which is of extremely infrequent occurrence. The average total annual precipitation amounts to only about 13 inches. However, a permanent pool of water exists at Old Glen Helen Station, located about six or seven miles to the north-east. The average annual evaporation in this area is believed to be in the neighbourhood of 10 feet.

The Nature of the Occurrence.—The nitrate occurs as disseminations beneath the hard surface crust of a prominence along the outcrop of the belt of dolomitic limestone, which is of Cambrian or pre-Cambrian age. To the south, distant only a couple of miles, is the wall-like upturned edges of the basal quartzites of the Larapintine Formation (Ordovician). This extends east and west. Five or six miles to the north is Mt. Zeil which, with other outstanding features of the northern flank of the McDonnell Ranges in the locality, are suggestive as representing portions of an overthrust or overfolded quartzite block probably of the same age as the foregoing.

The intervening area, wherein is the dolomite in question, is occupied by a rock formation which appears to be a twisted and deformed extension of that immense series of uniformly bedded, east and west trending, cryptozoon limestones, slates, and quartzites which extend regularly for 100 miles to the west of Alice Springs, underlying the Ordovician and overlying the crystalline pre-Cambrian.

For a distance of a mile and a half along the outcrop of the dolomitic limestone, occasional prominences are to be met with; the existence of each of these is due to local crustal hardening by silicification and ferruginization and the consequences of differential erosion. That where the nitrate deposit occurs is the most extensive of these. Apart from this particular one, indications of nitrate were observed in others of the prominences, but there appears to be no deposit of any importance connected with them.

The hard siliceous and ferruginous crusts are partly of a brecciated nature and appear to average only a few feet in thickness. That associated with the nitrate deposit is roughly 100 by 80 yards with an extension of another 30 yards as an offshoot in one direction. Over an area of about 50 by 30 yards towards the eastern side of the rise, the ground is cavernous below the hard crust, which is only a few feet in thickness. In places the crust has fractured and caved in.

The hard crust, more or less impervious to rain, appears to have originated by a superficial case-hardening process of silicification

and ferruginization. Such geological activities are frequently and widely evidenced in the arid interior of Australia. The brecciated nature of the crust rock is to be explained as a silicified residual breccia from the collapse of a cavernous area in the limestone belt. It would appear that here is the locus of a former long-existing cave area, now almost entirely obliterated by collapse and infilling of

FIG. 1. Entrance to cave under case-hardened crust. Nitrate deposit near Goyder's Pass, McDonnell Ranges, Central Australia.

cave earth. There are now only small, shallow caverns under the cappings, but in the past there may have been a more extensive system.

Small animals, such as lizards, snakes, bats, and wallabies, even now find shelter there. But there came under notice no present accumulation of guano beyond a small quantity of that black nitrogenous, pitch-like substance, so widely occurring in arid Australia and which is commonly and apparently rightly ascribed to bats.

On the eastern side of the rise a shallow cavern extends inwards below the crust for a few yards (fig. 1). The main evidence of the occurrence of nitrate is displayed in this. The latter substance appears as festoons on the wall and abundantly intercalated in the

rock itself (fig. 2). The latter is the rotten siliceous residue of the leached impure dolomitic limestone and is coloured and hardened by deposition of limonite. The saline matter with which it is saturated has assisted in the breaking down and recementation of the rock. The colour of the rock varies from a light ochreous character to a dark brown.

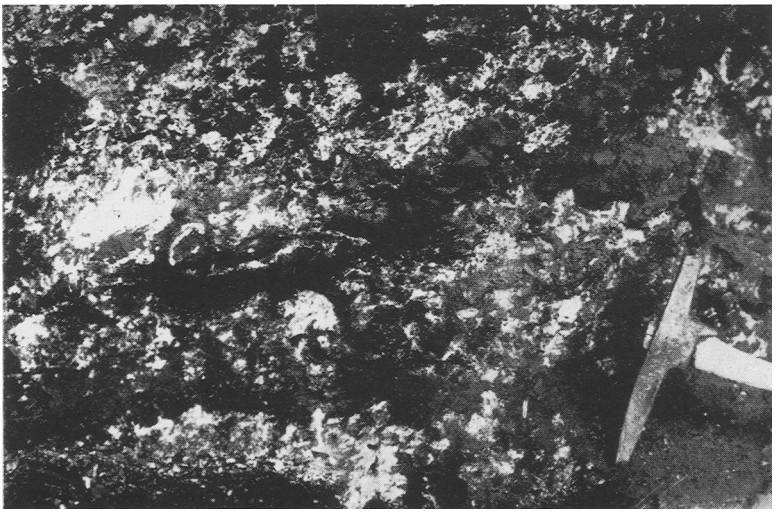

FIG. 2. View of the wall-face in the cave, showing the potassium nitrate as white impregnations through the rock.

The wall rock of the cave shows white encrustations and veining of nitrates. A picked sample of these white salts showed the presence of 99 % of nitrates of potassium and sodium, of which 95 % is potassium nitrate. An average sample of the wall rock taken towards the northern end of the face yielded on analysis 8·34 % of total soluble salts, of which 4·76 % was potassium nitrate. This sample was taken as a scaling over a height of 8 feet.

The richest face is on the south end of the cave wall. There the average value of a 4-foot vertical face is 22·14 % of soluble salts, of which 18·77 % is potassium nitrate.

The floor of the cave is occupied by detached blocks of the roof and wall rock embedded in a fine yellow ochreous powder. This latter, exposed in a winze which we sank 6 feet below the floor of the cave, was sampled and examined for potassium nitrate, but

returned only 0·72 % out of a total of 2·27 % of soluble salts. These figures are all the result of analyses by Mr. W. T. Chapman on samples carefully taken by C. T. Madigan and myself.

The potassium nitrate occurs for the most part either as saturations in the cave rock or as friable crystalline granular masses in pockets and veins in the wall rock. More rarely it appears as oriented,

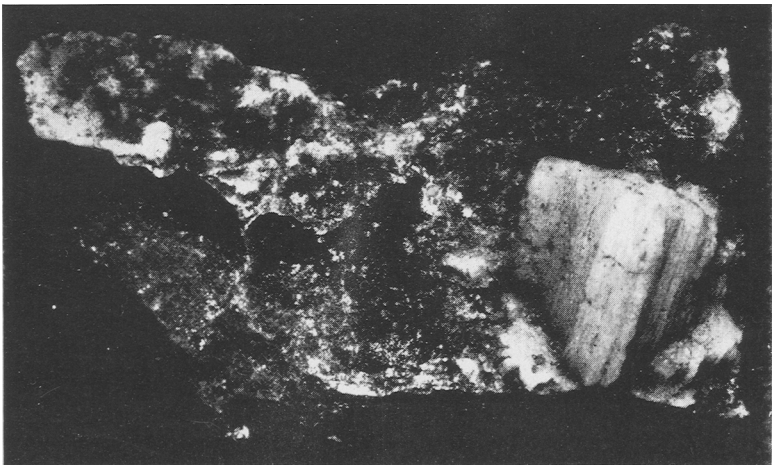

FIG. 3. A crystalline growth of potassium nitrate from a vugh.

crystalline growths from the wall of vughs. One of the best examples observed of these growths is shown in fig. 3.[1]

The Origin of the Nitrate.—There is nothing to suggest that the nitrate was originally a deposition contemporaneous with the sedimentation which developed the ancient dolomitic limestones. It appears to be an introduction of comparatively recent age in the geological sense. The most probable explanation is that in some manner it originated from the excreta of animals that, for ages past, had found a haven amongst these rocks and the collapsed cavernous formation there represented. The case-hardened surface sheds whatever rain falls upon it, so that below it there is no efficient downward leach whereby the belt above ground-water level would otherwise have been maintained comparatively free of such salts as nitrates.

The maintenance of soluble salts such as nitrates, therefore, owes

[1] The specimen figured has been presented to the British Museum collection of minerals.

much to the existence of an impervious case-hardened surface thereabouts. Small downward percolation of water, invading the ground below the crust along fracture lines would act as carriers for the nitrate impregnations; both assisting in its disseminations and in concentrating it elsewhere in vughs and fissures.

Some other occurrences of Mineral Nitrates in Australia.

Guano, principally derived from bats, is of common occurrence in caves in the ancient limestones of the Flinders Range of arid northern South Australia. Of these the caves north of Carrieton are famous for deposits of bat guano rich in salts of ammonia, which have arisen by bacterial changes in the guano, while it is maintained in a practically dry condition.

Farther north on Wooltana Station, near Mt. Warren Hastings, and about 85 miles east of Farina is another occurrence of a specially interesting nature. This cave is limited practically to one large, nearly vertical entrance descending from the summit of a prominent hill of pre-Cambrian limestone. Around the upper portion of the cave to a depth of quite 80 feet there is to be noted an abundance of the pitch-like bat guano in crevices and seams. The cavern descends almost vertically to a depth of about 300 feet, opening out below into a great and extensive vault, floored with a great depth of comminuted fragments of bat bones and other debris, with which are an abundance of almost pure ammonia compounds, principally sulphate and chloride.

A case corresponding in many respects with that of Goyder's Pass was described some years ago from a locality in South Australia in the 10-inch rainfall belt. There, at Elder Rock[1] near Paratoo, a case-hardened ferruginous breccia rises abruptly from the plain. Mineralized phosphatic residues, 'paratooite',[2] encrust the summit of the rock and ammoniacal salts, including ammonium nitrate, impregnate the underlying formation to a depth of quite 60 feet, as proved by mining operations. The ammoniacal salts were present to the extent of only 2 or 3 %. Analyses made at the time by the Mines Department indicated the presence of both ammonia and nitrate, and these constituents were recorded as ammonium nitrate.

[1] D. Mawson and W. T. Cooke, The phosphatic minerals of Elder Rock. Trans. Roy. Soc. S. Australia, 1907, vol. 31, p. 65.

[2] This material is very similar to corresponding phosphatic compounds recorded by A. Lacroix from several sources in other parts of the world.

In all these cases the fixed nitrogen can be sufficiently accounted for as a derivative of animal life attracted to the several localities by reason of the offer either of cave shelter or of the sanctuary and look-out afforded by a rocky hill top.

In the arid portions of Australia there is evidently a notable conservation of nitrogen in the soil. This has been noted [1] in the case of Western Australia by Dr. E. S. Simpson, the Government Mineralogist and Analyst. He states that 'Within an area bounded roughly by Lats. 24° and 30° S. and Longs. 116° and 124° E. the underground waters contain, in addition to the usual cyclic salts, an appreciable amount of a soluble nitrate'. Dr. Simpson found in these from a trace to 0·0362 %. The average of thirty-nine waters was 0·0111 % sodium nitrate, or nineteen parts of nitric nitrogen. He suggests that this is the result of active bacterial action in the soil. It is interesting that the region here referred to is notable for abundance of mulga scrub. Dr. Simpson points out that mulga is an acacia of the order leguminosae, considered to promote indirect fixation of nitrogen in the soil.

I am informed also that certain underground waters from the Tarcoola district, South Australia, examined by W. T. Chapman, Analyst to the Mines Department, have proved to contain notable quantities of nitrate nitrogen.

In seeking an explanation for this nitrate in the soil and groundwaters, there is also to be accounted the fact that the earth's surface the world over receives considerable contributions of nitrogen, fixed in the air by lightning discharge. It is estimated [2] that by this means 100,000,000 tons of nitrogen are fixed annually and carried to the earth's soil by rain, snow, and hail.

The leaching effect of abundant rainfall and the drain made by plants upon such soluble constituents of the soil does not ordinarily allow of the accumulation therein of nitrates. But in arid regions it may be that under special circumstances these constituents are accumulated in quite notable proportion. Hence, after useful falls of rain, the surprising fertility of Australia's arid lands.

[1] Bull. Geol. Survey W. Australia, 1916, no. 67, p. 143.

[2] Report on the fixation and utilization of nitrogen. War Dept. Pub.