

valleys in which they occur, even though today these valleys form a normal part of the river systems.

GEOLOGY.

4. The springs issue from the older group of Cretaceous sedimentary rocks which extend, on the surface, from the northern limit of Bende Division in the south to near Fika in Bornu Province in the north. These rocks are sandstones, shales and limestones, the sandstones being probably delta and off-shore deposits, the shales and limestones marine. In Northern Provinces Falconer established three main divisions, thus:-

- Upper - Grits, sandstones and ironstones.
- Middle - Limestones and shales.
- Lower - Sandstones.

He concluded that the salt came from the uppermost beds of the lower sandstones, which, he considered, might be impregnated with salt and to have been deposited under arid conditions. In Ogoja Province the lower sandstones and shales only are present in the areas concerned. The sandstones are not generally so well developed as they would appear to be in the north, judging by the emphasis which Falconer lays upon them there, but the shales are much thicker and apparently more extensive. Limestones which appear to be an important feature in the north are in the south quite subordinate to the shales with which they are interbedded. There is much intercalation of sandstone and shale and there is evidence that near Ogoja Station there is an important series of shales below the main sandstone division. Close to Gboko, the headquarters of Tiv Division, shales make contact with the old granite basement. Falconer found that this occurred in certain areas north of the Benue and assumed it was due to faulting, but at Gboko, although the actual contact cannot be seen, there is no reason for postulating a fault contact. While, therefore in the south there are two main divisions, sandstones and shales, they do not appear to be so well defined as in the north; nor is it safe to assume that sandstones everywhere form the base of the series, resting directly on the old granite floor.

5. These beds have been compressed into a series of folds which take the form of irregular anticlines and synclines or elongated domes and structural basins. Falconer remarked that the salt springs commonly occurred near the apices of the anticlines or domes. The brief investigations made in the neighbourhood of Ogoja Station confirmed this for the south and it has been known for some time that Uburu is situated near the top of an elongated dome. According to Falconer most of the springs in the north issue from sandstones. This is frequently but not invariably the case in the south. In the country of the Yala Clan the wells which have been excavated to obtain brine are in shales at Okpoma, in sandstone at Igbekureku and in sandstones with some interbedded shales at Ijegu. The Uburu seepage lies in sandstones. A spring close to Abakaliki Station issues from shales and there are no important beds of sandstone anywhere near. In the Tiv country exposures of bedrock are so rare that it was impossible to gain any idea of the detailed geology in the short time that could be spent there. From the nature of the soil it is obvious that

sandstones are abundant in those regions where springs and saline swamps occur.

ORIGIN OF THE BRINE.

6. From the examination of surface exposures there is nothing to indicate that beds of rock salt occur but this is of no value as evidence in a flat country of high rainfall in which such beds would be dissolved by subsurface water before erosion had a chance to expose them. The chief evidence against the case for existence of beds of rock salt, deposited contemporaneously with the sandstones and shales, is that these sediments are of types which are deposited in the sea or over the deltas of rivers. The great rock salt deposits of the world, excepting certain special types, were deposited in large inland lakes or seas under arid conditions. The beds associated with these deposits have certain unmistakable characteristics which the shales and sandstones of eastern Nigeria entirely lack. Falconer used the salt as argument for the associated sandstone being deposited under arid conditions but this argument cannot be admitted. The brine which in many of the world's great oilfields collects in anticlines below the oil is regarded as being derived from seawater imprisoned in the pore space of marine muds which later change to shales. The oil is formed from dead marine organisms likewise deposited with and imprisoned in these muds. Uplift and folding usually cause both salt and oil to be pressed out of the shales into sandstones that may be associated with them, migration over considerable distances often taking place. If suitable structures have developed as a result of folding, oil and brine may be trapped and form a reservoir in the sandstones. If folding and fracturing have been intense both may be dissipated, if not too intense the oil may disappear but a good proportion of the brine may be preserved. This last case probably represents what has happened in the more disturbed Cretaceous rocks of this country with which the brines under discussion are associated.

7. While the probability of rock salt having been deposited contemporaneously with the sediment is denied, it is possible that conditions might have arisen during the subsequent history of the strata allowing local deposition of salt from the brine. Such deposition would be most likely to occur within the space between the grains making up sandstones, resulting in a salt-impregnated sandstone. There are no geological guides to indicate where such deposits would be likely to be found.

8. From the evidence of the one or two springs actually seen and the shallow bores put down at Awe by the Northern Nigeria Mineral Survey, and from the descriptions of the inhabitants of salt producing towns, it is certain that many of the brines arrive at the surface under some slight pressure. The classical theory of artesian water fails to account for this pressure and it is more likely that the ever present force of rock-weight is slowly displacing the brine upwards. It thus tends to collect in sandstones in the anticlines and domes. Having arrived close to surface it takes advantage of cracks or lines of weakness in the rocks and established channels for itself up which it flows to issue as springs.

STRENGTH OF BRINES.

9. During the investigation most of the springs were submerged under fresh surface water or were still dilute on account of its ingress during the rains. At Abakaliki and Awe samples of brine, apparently undiluted were obtained. At Igbekureku the sample obtained may have been representative of true brine or it may have been somewhat diluted. In January the District Officer, Ogoja Division, collected a sample from Okpoma, the wells by then having been cleared and drawn from by the salt producers. Following are the concentrations of these brines, expressed in grams per 100 cubic centimetres, which in the case of dilute brine approximates actual percentage of salts:-

Awe	(a)	Natural Seepage	0.78
	(b)	N.N.M.S. Bore No.1	0.77
	(c)	N.N.M.S. Bore No.2	0.74
Okpoma ..	..	..	1.29
Igbekureku	..	..	1.79
Abakaliki	..	..	1.20

The strength of normal seawater is about $3\frac{1}{2}$ per cent so that it is obvious that these brines are weak compared with it.

10. Later in the dry season samples were collected from Uburu and Okposi by the District Officer, Afikpo Division, and from a number of sources at Arofu and Akwana, Wukari Division, by Mr. C.C. Graham, Foreman of this Department. Some of these turned out to be very much stronger, as the following results show :-

Uburu ..	..	..	..	5.97
Okposi ..	..	..	..	5.65
Akwana	(a)	Singa Pool	5.18	
	(b)	Tanta	0.56	
	(c)	Azanka	1.95	
Arofu ..	..	..	..	2.04

If the stronger of these brines have not undergone concentration by natural means they are worthy of further investigation, especially that of Singa Pool at Akwana. It is possible however that this pool, Uburu Lake and the Okposi source, which has never been seen, have been concentrated by natural evaporation. In this connexion there is some doubt about the true strength of Okpoma brines. During the investigation samples were taken from several storage posts in compounds which were said to have been untouched since the previous dry season when they were collected. One sample contained 5.59 gm/100 c.c. and another 4.94. When the true sample was obtained in January these results were discarded as valueless and it was concluded that the brines had been concentrated by evaporation over fires, the method used for obtaining the salt at Okpoma. Support was given to this view by the fact that the concentrations of every pot differed, some being quite weak. There does seem however a slight possibility that these brines do become more concentrated as the dry season progresses. A sample collected in February by the Assistant District Officer, Abakaliki, from the Abakaliki spring, showed that this brine had increased in strength from its original 1.20 gm/100 c.c. to 1.43. The evidence for change in concentration with progress of the dry season is not very conclusive as

all that can be said is, that during the rains and for some time after they have ceased the brine is subject to dilution by surface and subsurface fresh water; but that where it collects in open pools, natural evaporation may be sufficient to effect considerable concentration despite the continual ingress of subsurface fresh water. A real assessment of the strength of the brines must be left until more bores can be put down to a depth at which subsurface fresh water has little effect.

QUALITY OF THE SALT.

11. The quality of the salts obtained from these brines is generally good. Sodium chloride is by far the most important constituent and the amounts of impurity in the form of calcium magnesium and potassium or the sulphate and carbonate radicles are usually small and insufficient to impair the value of the salt. All analyses previously recorded seem to have been made on samples of salt prepared by the salt workers. Analyses made at the laboratory of this Department seem to indicate that these are not representative of the salts of the brines and it is presumed that owing to fractional crystallization the native made salts may contain unduly high percentages of certain constituents. For example, four Awe salts analysed at the Imperial Institute show a range of potassium chloride content from 8.2% to 2.8% whereas a sample of well powdered and mixed salt obtained by complete evaporation of the brine at the Departmental laboratory gave only 1.6 per cent. Likewise an analysis of Uburu salt supplied by the Agricultural Department indicated about 7 per cent whereas one made on salt prepared in the laboratory from the brine contained only 1.16 per cent. It is possible that the leaching process, used at both, these workings and to be described later, causes this increase in potassium chloride content. In general it can be said that these brines have a composition similar to that of seawater, the amounts of the constituents classed as impurities sometimes being slightly greater and sometimes slightly less than those of the average seawater.

NATIVE METHODS OF PREPARING SALT.

12. The method of preparing salt varies somewhat in the different workings but the final process is always evaporation to dryness in crude earthenware pots over an open fire. Needless to say this is extremely inefficient and wasteful of fuel, a commodity which is now generally scarce in the immediate neighbourhood of salt-producing towns. So far as could be seen and learned in the Yala country of Ogaja most or all of the evaporation is done thus, little or no use being made of natural evaporation. Little was being done at the time these villages were visited and the atmosphere of passive resistance in which the investigation was carried out was not conducive to eliciting information. There was no evidence of drying beds of any kind. A small salt community which has been producing for about ten years from a spring some four miles south-south-east of Moi Igbo railway station, south of Makurdi in Tiv Division, appear to use only artificial evaporation, wood still being plentiful in the district.

13. The old established works at Keana and Awe make use of natural evaporation to some extent. The Keana industry seems especially well organized. Concentration is carried out on prepared hard mud floors divided into compartments. Thin layers of mud are spread on these floors and sprinkled at intervals with brine from the spring until the mud becomes impregnated with a considerable amount of salt. It is then collected and placed in earthenware pots which have a small hole in the bottom. Brine is poured into the pot in small quantities at a time and as it passes downwards through the mud it leaches out the salt and a concentrated solution drips through the hole into a receptacle. This solution is then evaporated in pots over an open fire. At Awe the general method is the same but the impregnated mud is made at the protruding edges of tilted sandstone beds provide compartments. Mud is placed in these and absorbs the brine, a balance being established between the amount of brine absorbed and the loss by evaporation. The mud is left for forty days by which time it is impregnated with salt and is then treated as at Keana. A sample of concentrated brine from a leaching pot, ready for artificial evaporation, contained 18.47 gm/100 c.c. representing a twenty-fourfold concentration by natural evaporation. The process is carried out only once every dry season. The method is wasteful and inefficient because if the supply of brine is greater than the amount of water lost by evaporation it runs or seeps away and is wasted. The Awe people complain that the bores put down by the Northern Nigerian Mineral Survey has spoiled a large area of natural evaporating pans which now are permanently flooded. The flow from one of these was 2700 gallons an hour when the hole was first drilled and it may still be something in this order were the bore cleaned out. One can say that at least 500 gallons an hour of 0.75% brine is running to waste and in fact has been for the past thirty five years, representing a loss of 147 tons of salt a year. This is probably a conservative estimate. The people have made no effort to adjust their method of producing salt to cope with this generous supply of brine. It was a matter of some surprise to notice that good white salt deposited in crusts on the rocks, instead of being scraped off and collected, was disregarded and covered with mud put down to absorb the brine. The Awe springs, augmented by the bores, yield far more brine than any other locality and yet production figures are not comparatively greater, having regard to the fact that the brine is weaker than elsewhere. The industry is in fact most inefficient and the remark of an official that it could not be expanded and should not be interfered with hardly calls for comments.

14. From the description in Bulletin No.8 of the Department it is not clear whether at Uburu partial natural evaporation is used or not but the brine is mixed with mud which is leached in pots prior to artificial evaporation. A sample of brine from the leaching pots gave gm/100 c.c. as against about 5 gm for the original brine. Concentration must therefore be effected by some means.

RECOMMENDATIONS.

15. To increase salt production from these brines there must be a much larger supply available and more efficient methods of evaporation must be used. Natural evaporation by the heat of the sun must be availed of; otherwise it would be better to produce salt from seawater by artificial evaporation since wood is generally easily available along the coast.

16. On data obtained by the Northern Nigerian Mineral Survey the chemists of the Imperial Institute suggested a scheme for producing salt on a larger scale at Awe, following methods used in certain European Countries. A series of long brushwood walls are constructed parallel with the direction of the prevailing winds. Brine is pumped up and distributed over them so that it trickles slowly down into channels, along which it is led to evaporating pans constructed in the ground near by. The large surface of brine exposed on the brushwood causes rapid evaporation and the brine which runs into the evaporating pans is a concentrated and clean solution. Final evaporation, with precipitation of salt, is effected in the open pans. This method, without modification, should be successful during the dry season in Nigeria. During the rains evaporation on the brushwood walls could be continued but final evaporation would have to be done by artificial hear under cover. The brushwood walls would be built in lines trending north-east to south-west. The supply of brine to be fed to them would be regulated according to temperature and humidity.

17. The success of this method of production will depend upon the length of the dry season, accordingly attention should be directed to these sources of brine farther north. Although at Awe it is known that a copious supply could be obtained the brine is weak. In view of the apparently greater strength of that at Akwana it is proposed to bore to depths of about one hundred feet to test the real strength and determine the yield. This work would in fact have been under way but for the fact that officer who was to have done it was required for more urgent work connected with the war. Another source which it is hoped to investigate is the pool near Moi Igbo Railway Station, south of Makurdi. In early December when it was still apparently diluted by fresh water the salt content of the brine was 0.65 gm/100 c.c. so that there is reason to suppose that its real content is greater. It has the advantage of being near the railway. There are sources within a few miles of Makurdi itself. These have never been seriously worked by the people living near them. They occur in flat swampy country covered by alluvium and drift near the Benue and are detected by small incrustations of salt on the surface and saltiness of the soil. A pit sunk to depth of about ten feet made too much fresh subsurface water to provide data on the strength of the brine. They might be worth investigating at a later date.

18. An important factor in the economics of production will be the ease and cheapness of pumping the salt to the brushwood walls. It would be highly desirable to find a source of brine under sufficient natural pressure to raise it to the required level. If such could be found even though it were not very strong it would be well worth while to develop it.

19. Should it be decided to increase salt production the question arises whether it should be done through the present owners of the industries or an outside agency. In those cases where the industries have been in existence for a long time the owners and in fact the whole towns or clans concerned are against interference of any kind. Keana may be an exception a

the chief and his followers seemed to adopt a reasonable attitude when it was suggested that they might be helped to improve their methods. If however they could be shown that greatly increased production, with a corresponding increase in their wealth, could be attained, they might be willing to co-operate and production once properly organized, could be left in their hands, under supervision. Practically the only equipment which they would need to have supplied would be pumps and pipes for distribution of the brine over the walls. If opposition is strong, production at a source not hitherto used might be established to demonstrate the greater efficiency of the brushwood wall method of evaporation. For this purpose the sources near Makurdi might be used if the supply and strength of the brine prove to be satisfactory. The salt workers at the pool near Moi Igbo might be prevailed upon to co-operate and agree to the use of their pool.

20. It is suggested that the industries in Ogoja Province should be left to themselves until the method proposed has been tried in the Benue Valley and data upon the rates of evaporation under various atmospheric conditions obtained. It may be found that evaporation on the walls is too slow even during the drier days of the wet season to be feasible, in which case it would be hardly worth while introducing the method at places as far south as Uburu where the dry season is short and broken by periods of considerable humidity.

21. There are a number of small sources of brine in Gombe, Shendam and Jalingo Divisions. It has not been possible to investigate these though a visit was made to a small salty mud pond at the village of Gujba or Gujbawo, near Tumu in Gombe Emirate. It is hoped to obtain a sample of brine from a pit to be sunk on the edge of the pond. Given a good supply of reasonably strong brine natural evaporation should be most efficient in those far northern areas where the dry season is long. Their chief disadvantage is their distance from lines of cheap transport.

unction,
April, 1942.