COPY 3

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF SUPPLY AND DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Report No. 1949/99.
(Geol. Ser. No.67).

NOTES ON LATERITISATION AND THE ORIGIN OF OPAL IN AUSTRALIA.

by

L.C. Noakes
Geologist

CANBERRA, A.C.T. 21st September, 1949.

CONTENTS

NOTES ON LATERITISATION AND THE ORIGIN OF OPAL IN AUSTRALIA.

by

L.C. Noakes
Geologist

Report No. 1949/99.
(Geol. Ser. No. 67)

SUMMARY.

These notes on lateritisation and the origin of opal have been prepared for the benefit of officers of the Bureau whose work brings them into contact with the effects of lateritisation. Discussion of the ideas presented herein is invited. At a later date, a full report on several aspects of lateritisation in Australia will be submitted by officers of the Northern Australia Regional Survey and of the Bureau of Mineral Resources, Geology and Geophysics.

It is shown that deposits of opal, in most opal fields in Australia, occur within a mature lateritic profile which developed on a continent-wide peneplain in Upper Tertiary time. The zones of a laterite and the movement of silica within the profile are discussed and related to the occurrence of opal.

The conclusion is therefore drawn that the theory that opal deposits were produced under arid climatic conditions and that their occurrence is roughly limited by the present 15" isohyet may therefore be discounted and deposits of opal may be expected in any areas in which sub-horizontal beds of sandstone and shale have been lateritised.

INTRODUCTION.

In 1946 and 1947 the writer had excellent opportunities to study the effect of lateritisation in the course of geological reconnaissances in Northern Australia. This work has been shared by G.A. Stewart, Soil Officer, Commonwealth Scientific and Industrial Research Organisation, and D.M. Traves, Bureau of Mineral Resources.

From field evidence which has been collected on several aspects of lateritisation - origin, products and relationship to geomorphological processes - a detailed account of lateritisation in Australia can be given.

Much of this work will be based on that of earlier investigators, particularly David, Woolnough and Whitehouse, in the geological field, but some of the postulates of these and other workers are believed to be incorrect.

Apart from some information on laterites and lateritisation in the Katherine-Darwin Region which appeared in preliminary reports of the Northern Australia Regional Survey (Noakes, 1947; Stewart, 1947), and preliminary notes on the nomenclature of laterite profiles which were circulated in the Bureau in 1948 (Noakes and Traves, 1949), this work on laterites has not yet been assembled in report form partly because of insufficient time, but mainly because the work is incomplete. However, it is intended that most aspects of lateritisation shall be dealt with in the near future in a joint report by the abovementioned workers together with H.B. Owen, Bureau of Mineral Resources, who has, during the past five years, made a particular study of aluminous laterite in Australia.

During the work on laterites in Northern Australia, it became increasingly clear that the occurrence of common and precious opal in surface rocks in Central and Northern Australia represented one more aspect of Tertiary lateritisation. Whitehouse (1940) was the first to connect the occurrence of precious opal in Western Queensland with the process of lateritisation; although he has not discussed the origin of the opal in detail.

The most prominent of earlier workers in this field are L.K. Ward, E.C. Andrews and W.G. Woolnough. Ward (1916) recognised the close association between the opal deposits and the widespread silicification of surface rock in Central Australia and suggested that the opal was a special phase of the silicification, largely due to the arid climate of the region. Ward pointed out that most of the opal deposits were situated within the present 15" isohyet and thus inferred that the occurrence of the opal was governed by Recent climatic conditions.

Andrews (1924) investigated the opal deposits at Lightning Ridge in N.S.W., and suggested that the surface silicification, of which ~~which~~ the opal formed a part, was the result of upward movement of hydrous silica by capillarity in Upper Tertiary time. He suggested that the climate at that time was variable with changes from humid to arid conditions.

Woolnough (1927) also favoured the theory that surface silicification was the result of upward movement of solution by capillarity and regarded the occurrence of precious opal in Central Australia as a result of the same process of surface silicification which produced what he called the "Duricrust" on a continent-wide peneplain in Miocene time.

The work that has been done recently on lateritisation suggests that the dominant factors governing the origin and distribution of precious opal in most Australian opal fields are as follow:-

1. Precious opal, in most Australian fields, is one of the products of widespread, mature lateritisation which took place, under conditions of high, mainly seasonal, rainfall, on a very mature land surface in Miocene time.

2. The opal was deposited in the lateritic profile as part of the process by which silica is transported <u>down</u> the profile and is re-precipitated to impregnate leached parent material or to form opal.

3. The age of the laterites and accompanying opal is certainly Tertiary, probably Miocene, and therefore, the distribution of opal cannot be governed by any present day climatic features.

4. Important factors in the distribution of known occurrences of precious opal are -

   a. Lower Cretaceous sediments and sediments of the Eyrian Series (shale and sandstone) are suitable rocks for movement of silica and deposition of opal under lateritisation.

b. The region is one in which the deep lateritic profile has been dissected to expose the pallid zone and to allow easy prospecting in the most favourable zone.

c. In other parts of the continent where laterites developed on beds which were probably suitable, the laterite has been removed, or has not yet been sufficiently dissected to encourage prospecting.

These salient points are discussed briefly in the following notes in which a discussion on lateritisation was an essential starting point. Many of the ideas put forward in the section on the lateritic profile represent the combined work of the four officers mentioned above, and, in particular, the work of G. A. Stewart.

LATERITISATION.

Geomorphological Aspects of Lateritisation.

The essential conditions under which lateritic profiles can develop to maturity are a stable soil profile, fairly high, monsoonal rainfall and temperate or tropical temperature conditions. The importance of these conditions as factors in the development of laterite is discussed in the succeeding section, but they also indicate the essential topographic conditions under which laterite can form.

For the development of mature laterite over wide continental areas, the land surface must be in an advanced stage of maturity approaching peneplanation, because only under such conditions will a soil profile be sufficiently stable to weather deeply and enable the process of lateritisation to be completed. The stream systems must be sufficiently close to grade to be incapable of significant erosion under conditions of fairly high rainfall. Conditions such as these are only produced over wide areas when continents have been sufficiently stable to allow a cycle of erosion to be virtually completed.

It follows that widespread, mature lateritisation infers peneplanation of continental areas under fairly critical climatic conditions and it is therefore not surprising that field evidence in Australia suggests that all of our mature laterites may be referred to one period in the Upper Tertiary, when these critical conditions were fulfilled.

Woolnough (1927) recognised the continental character of this very mature Tertiary land surface although he did not connect the characteristic weathering which developed on its surface with lateritisation. The work of the Northern Australia Regional Survey has confirmed Woolnough's Tertiary land surface, and the writer has no doubt that the mature laterites personally investigated in the Northern Territory, Western Queensland, New South Wales, and in Southern Australia can be referred to the same land surface, although admittedly the time of commencement and termination and the length of the interval of lateritisation seems to have varied in widely separated regions.

Whitehouse (1940, p.17) suggested that there were two periods of lateritisation in Queensland, but, although there has been no opportunity to examine all of Whitehouse's sections, Stewart and Traves examined his section near Riversleigh and cannot agree with his interpretation (Whitehouse, 1940, p.27). Furthermore, the laterites of the Northern Territory have been followed into Western Queensland and no evidence of two periods of lateritisation has been observed. It may be noted that slight differences in level between outliers of laterites does not necessarily mean that there was more than one period of lateritisation. The Tertiary land surface was not flat but very mature with gentle but definite undulations which can be followed very clearly in some places. Furthermore, the old land surface has been subjected to differential vertical movements and definite normal faulting has been traced in the Northern Territory.

Woolnough (1927) suggested that this old land surface reached maturity in Miocene epoch, and recent evidence on the age of lateritisation confirms the earlier opinion.

The most significant evidence on the age of laterites is -

1. In parts of Queensland, New South Wales and South Australia the laterite has been developed on sediments of the Eyrian Series of Eocene age.

2. In recent field work in the Giralia area of North West Basin, Western Australia, laterites were found on Eocene sediments covered by Middle ~~(?)~~ Miocene strata. On the Cape Range, two thin layers of silicified and iron stained material have been observed by N.H. Fisher interbedded with Middle ~~(?)~~ Miocene limestones. These layers may represent interrupted periods of lateritisation on limestone in Middle ~~(?)~~ Miocene time.

3. In the North West Basin, Teichert* found laterites developed on Miocene sediments, which he thinks may be Middle Miocene in age.

In the detailed paper on lateritisation the occurrence of laterite and the age of formation in Australia will be discussed in full and evidence will be presented indicating a period in the Tertiary in which widespread lateritisation was common to many continents.

It is apparent, therefore, from the geomorphological aspects of lateritisation in Australia, that, if the occurrence of precious opal can be attributed to processes of lateritisation, then the opal was formed about Miocene time and its present distribution in Australia cannot be governed by recent climatic conditions.

The Lateritic Profile.

General. In lateritic profiles developed to maturity on suitable parent rock, a number of zones can be distinguished. These are, from the surface down - surface soil, the ferruginous zone, mottled zone, and pallid zone. In addition, irregular silicification may occur, particularly in portions of the mottled and pallid zones so that a silicified zone or zones may be present. Whitehouse (1940) has discussed these zones of a laterite but his explanation of the processes is somewhat different from that presented here.

---

* Personal communication.

The pallid zone consists of more or less leached parent rock lying below the average-dry-period water table. The original structure of the parent rock is discernible in most places, although translocation of iron to give white or light coloured rocks is commonly well advanced. Some degree of leaching of the alkalis, alkaline earths and silica may be expected. The mottled zone is formed by the seasonal fluctuation of the water table and is roughly bounded by the lower and upper limits of the water table. The mottled zone is one of severe leaching and in most places consists of kaolin or other end products, with iron staining commonly in patches.

The ferruginous zone forms at the upper limit of the water table and consists largely of iron and aluminium oxides - being leached parent material impregnated with iron with subordinate manganese or silica. Concretionary forms are common in the ferruginous zone which may form a massive horizon or may be represented only by scattered iron concretions (ironstone, gravel, pisolitic gravel).

Silicified material may occur in either the pallid or mottled zones but more rarely in the ferruginous zone. It is formed by the impregnation of leached parent material by secondary silica and the products can be divided into two general classes. When sandy material, sand, or sandstone forms the host rock, a glassy, hard quartzite, commonly called billy or grey billy results, and when shales or clays are impregnated a fine, tough rock is produced which has been commonly called "porcellanite". Miss Crespin has found that "porcellanite" from many places in Central and Northern Australia contains radiolaria and the possible significance of these silica-secreting organisms is discussed in a later section.

The significance of these zones can best be shown by tracing the processes consequent on the seasonal fluctuation of the water table. In the pallid zone, below the water table, anaerobic conditions - probably bacterial - prevail. Iron is reduced and is taken in solution as ferrous compounds. Some of the iron in solution probably escapes from the profile but some is re-oxidised and deposited at the surface of the water table. Some of the parent rock is broken down by the removal of alkalis and alkaline earths and some solution of silica is apparent. However, the movement of silica will be discussed in a succeeding section.

At the onset of the wet season, the water table rises (probably quickly in response to the storms which normally occur), and throughout the season the mottled zone is water-logged and iron is deposited in the ferruginous zone at the wet season water table. At the end of the wet season, the water table slowly falls through the mottled zone, until the lowest level of the water table is reached at the end of the dry season. Given time, the mottled zone is completely leached of soluble constituents - mainly alkalis and alkaline earths - by this alternating cycle and an end point is reached when the zone consists of aluminous silicates and oxides, with or without secondary silicification, some iron staining, and any insoluble constituents of the parent material. The proportions of aluminous silicates and aluminous oxides and the extent of silicification indicates with what degree of success the leaching solutions have been able to dissolve and transport silica. Some portions of the zone are impregnated with iron as the water table falls, but at least some of this is leached out in the succeeding wet seasons - the process giving rise to a mottled appearance from which the zone is named. Iron impregnated zones are seen in some profiles at the top of the pallid zones, where iron is deposited at the water table toward the end of the dry season, but it is not common, since solution in succeeding wet periods tends to remove it.

Laterite profiles in many places do not conform exactly to the ideal pattern because of variations in topography and climate, but the main reason for variation is found in the composition of the parent material. A lateritic profile can only be fully-developed when the parent rock has sufficient alumina and iron to allow the several zones to be developed. Aluminous rocks, with little iron, will produce pallid and mottled zones without a distinct ferruginous zone. In rocks such as basalt, with high iron content, the mottled zone is not clearly distinguished because it is heavily impregnated with iron and tends to merge with the ferruginous zone. Furthermore, the limits of the three main zones are commonly not well-defined because the upper and lower limits of the water table fluctuate with variations in seasonal rainfalls and also, with time, the zones tend to move down the profile as erosion is probably never completely halted.

In Table I, the average chemical composition of seventeen common rock types is listed. It can easily be seen that an average sandstone will not give rise to a well-developed lateritic profile, because of its lack of iron and alumina. Rhyolite should produce pallid and mottled zones but little ferruginous zone. On the other hand, shale could give rise to a complete profile, as should syenite and diorite. Basalt, with high iron, gives a complete profile but an abnormally ferruginous mottled zone. The average composition of limestone shows that it cannot be expected to yield a normal lateritic profile, with little iron and alumina, and the result of lateritisation is commonly a deep soil-sandy or clayey depending on the nature of the residual minerals in the limestone - with varying concentration of iron.

TABLE I.

Chemical Composition of Common Rock Types

Rock	$K_2O.Na_2O$ Alkalis	CaO.MgO Alkaline earths	Total Alkalis & Alkaline earths	Al_2O_3	SiO_2	Total Iron	Free Silica
Sandstone	1.77	6.69	8.46	4.78	78.66	1.38	Variable high.
Rhyolite	7.6	1.7	9.3	13.9	72.6	2.2	Variable
Granite	8.3	2.1	10.4	13.1	72.0	3.3	10-22%(?)
Alkaline granite	9.5	.7	10.2	12.5	73.2	3.2	10% +
Shale	4.6	5.6	10.2	15.47	58.38	6.5	Low
Dacite	6.6	4.5	11.1	16.6	66.9	3.9	Low 2%
Granodiorite	6.3	5.6	11.9	15.3	66	4.9	2%
Trachyte	10.1	4.2	14.3	17.7	60.7	5.3	-
Quartz-Diorite	4.9	11.0	14.9	16.5	59.5	6.7	1% ±
Syenite	8.3	7.6	15.9	16.4	58.6	6.7	-
Diorite	5.5	10.9	16.4	16.7	56.8	7.6	-
Anorthosite	4.4	13.8	18.2	28.3	50.4	2.2	-
Basalt	4.8	14.9	19.7	15.8	48.8	11.7	-
Trachy-basalt	6.7	13.6	20.3	16.0	48.8	10.6	-
Gabbro	3.4	18.5	21.9	17.9	48.2	9.2	-
Peridotite	1.5	36.6	38.1	4.8	41.1	11.1	-
Limestone	.4	50.5	51.0	.8	5.1	.5	-

Chemical analyses taken from "The Principles of Petrology" by G.W. Tyrell and from "Treatise on Sedimentation" by W.H. Twenhofel.

Movement of Silica in the Lateritic Profile. The starting point for discussing the movement of silica is provided by the occurrence of aluminous laterite (commonly called bauxite). The aluminous laterite is typically developed on basic rocks such as basalt and consists almost entirely of aluminium hydrates with varying amounts of iron oxides. This material is found mainly in the mottled zone and is an end product of leaching. The combined silica in the parent material, about 48% has been reduced to as low as less than 1%. There is no doubt that the removal of this silica was an integral part of the process of lateritisation and there is also no doubt that the silica was removed downwards. The same process is apparent in the profiles of many normal laterites in that portion of the combined silica has been leached from portions of the mottled or pallid zone but the process has not been completed. Combined silica is still present in the profile and much of the silica which was dissolved did not travel far, but was re-precipitated lower in the profile to form grey billy or "porcellanite".

It is interesting to note that Van Bemmelen (1941) in a deep lateritic profile in Bintan Island, Netherlands East Indies, found probable secondary silicification in the pallid zone about 80 feet below high-grade aluminous laterite and approximately 100 feet below the surface. H.B. Owen has noted silicification below some aluminous laterites in the Moss Vale district, New South Wales.

The processes by which silica is dissolved, transported and reprecipitated within the laterite profile is not clearly understood, and no review of current theories is intended at this stage. However, H.B. Owen and L. C. Noakes suggest as a working hypotheses that the total amount of alkalis and alkaline earths present in the parent rock may be the major factor in the leaching, transport and reprecipitation of silica. Silica can be dissolved in alkaline solutions (Clarke, 1924) and can be transported provided the alkalinity of the solutions remains sufficiently high. In Table I. the combined percentage of alkalis and alkaline earths in common rock types is listed and it is significant that the rocks on which aluminous laterite is commonly developed - basalt, syenite, gabbro, diorite, etc. - show high figures. In lateritic profiles developed on these rocks, silica may be leached, particularly from the mottled zone, by alkaline solutions and the alkalinity of the ground water, at least in the upper portion of the profile, is sufficiently high to allow most of the silica to be transported at least as far as the lower portions of the pallid zone.

Although most aluminous laterites are developed on basic rocks or on alkaline rocks like syenite, some have been found on shales or slates, on granitic rocks and on metamorphic products. These occurrences are rare, but can be expected, since any of these rocks, if abnormally rich in alkalis and alkaline earths and possessing the required alumina, may give rise to aluminous laterite.

However, in most lateritic profiles the end point is not aluminous laterite mainly because of insufficient alkalis and alkaline earths, although to some extent the leaching of silica has taken place. Silica may be transported in colloidal form but only under fairly critical conditions, and it is suggested that, where the alkalinity of the transporting solution is reduced, silica is thrown down, in amorphous form to produce "porcellanite", billy or opal. In the laterites of the Northern Territory, these processes seem best developed in the upper part of the pallid zone extending into the mottled zone, but have also taken place lower down in the profile. Some opaline silica is found in the ferruginous zone in some places.

This was probably derived from leached parent material in the ferruginous zone, or may have been deposited, with iron, at the wet season water table.

The occurrence of precious opal in lateritic profiles in Australia is, of course, a part of this process by which silica, originally combined in the parent rock, is leached, moved down the profile to some extent, and is re-precipitated in opaline form.

Finally, there are two important points which should be mentioned in this section of the report. Whitehouse (1940, p.19) and others have suggested that some features of lateritic profiles in Australia are due to alteration of original laterites by succeeding climatic cycles. In the writer's view, this idea cannot be supported. The laterites were developed to maturity, so that to all intents and purposes, an end point was reached for each profile. Short of mechanical disintegration, succeeding climatic cycles could effect little change in these stable profiles, apart from some possible re-distribution of iron.

The second point is that the whiteness and leached appearance of many of the sediments which outcrop in mesas or on the edge of small plateaux, and which are so distinctive in Central Australia, is commonly considered a result of desert weathering, in an arid cycle such as that which can be studied in parts of Australia at the present time. However, in the writer's opinion this is not correct. The whiteness of these rocks which lie mainly in the pallid zone of the Tertiary lateritic profile, is due to lateritisation under tropical rather than arid conditions. In the Northern Territory, shale from well below the pallid zone are greeny-grey in colour, and if these were subjected to surface weathering under arid conditions, they would not become white and heavily leached, but rather buff or variable in colour with very irregular distribution of iron staining.

Nomenclature. Work on the nomenclature of laterite profiles is incomplete but the following suggestions have been made.

The term "laterite" may be used as a group term referring to all or any of the zones of the profile. The term was applied by Buchanan in India to material which came from either the ferruginous or mottled zone. On this account, the meaning of the term has been restricted in some circles to the ferruginous zone.

The terms 'ferruginous zone', "mottled zone', 'pallid zone' and 'silicified zone' may be used wherever these zones can be identified.

The terms 'billy' and 'grey billy', introduced by Dunstan in 1900 may be used for the secondary quartzite, resulting from silicification of sandy-material or sandstones in the lateritic profile.

A suitable name for the silicified shales and clays has not yet been found. The term "porcellanite" is not considered suitable because it is widely used to describe a sedimentary rock which has no connection with lateritisation.

It is suggested that the use of the term "duricrust", introduced by Woolnough in 1927, should be reconsidered. In the first place, Woolnough coined the term because he considered that the products of weathering he wished to describe were not laterites, hence a new word was required (Woolnough, 1927, p.25). In the second place, the term "duricrust" is inevitably associated with the suggested process by which it was formed - upward movement of silica and iron by capillarity. There is considerable doubt whether this process can explain the occurrence of silicified rocks such as billy or "percellanite". Pedologists have realised for many years that, although movement of water by capillarity probably does take place in rocks, the range of vertical movement is very restricted. Kellogg (1943) states that under the best conditions for movement, provided by well packed fine sand or silt with little clay, water will move up to the surface from several feet, but where there is much clay or where the host material is coarse sand, little movement of water will result.

OCCURRENCE OF OPAL.

Geological Features of the Opal Fields.

The opal* fields occur either on Lower Cretaceous shales and sandstones or on sediments of the Eyrian Series. Croll (1948) has provided a summary of the geological features of the fields from which opal is still being won and Jackson (1902a) gives details of many of the old fields in Queensland.

All of these fields have geological features in common whether they be on marine strata of Lower Cretaceous age or on fresh-water sediments of Eocene age - the geological section consists of a deep, lateritic profile developed on sub-horizontal shales and sandstones, in which are found irregular leaching and secondary silicification.

For the most part these sections represent the pallid zone of the lateritic profile but it is difficult to determine from geological descriptions whether portions of the mottled and ferruginous zone are represented. Judging by the geological section at White Cliffs, which the writer visited some years ago, the prominent surface bed of grey billy at White Cliffs, Lightning Ridge, Coober Pedy and Andamooka may have been formed by silicification of a sandstone bed probably low in the mottled zone. It seems likely that the ferruginous zone, in these sections, was not massive, because of the small quantity of iron available, and this led to subsequent removal of the ferruginous zone and any unsilicified mottled zone material. An example of this process is provided by the lateritic profiles on some of the mesas in the Katherine-Darwin region where the profile on Lower Cretaceous shales is now represented by silicified shales of the pallid and mottled zones with only a little loose pisolitic gravel to represent the eroded upper portions of the profile. Cribb (1948), following Whitehouse, has described a full lateritic profile from messas in the Eyrian series at the Hayricks Opal Mine, Queensland, in which the ferruginous zone is very thin and not massive.

The complete or partial leaching of the beds exposed on the opal fields is shown by the dominant light colour of the rocks particularly of the shales; the occurrence in places, as at Lightning Ridge, of soft porous sandstone, almost certainly leached calcareous sandstone; and the movement of silica down the profile.

* The term opal as here used embraces both common and precious opal. The reason why some opal possesses play of colours is not adequately understood.

The major source of this silica is probably to be found in the breaking down of silicate minerals by alkaline solutions, although other sources of silica may be present in some sediments. In 1947, the writer suggested that the tests of radiolaria may have been a major source of the silica cementing the "porcellanites" in lateritic profiles on Lower Cretaceous shales in the Katherine-Darwin region (Noakes, 1947) and Crespin (1948) has suggested the same process in Lower Cretaceous beds at Coober Pedy. However, although it is probable that some silica has been derived from this source, the fact that secondary silicification is also prominent in profiles developed in fresh water sediments of the Eyrian Series clearly indicates that the presence of radiolaria is not a major factor in secondary silicification.

In general, the occurrence of grey billy in these profiles denotes an original sandstone or sandy sediment which has been silicified. Sandstones, although poor sources of silica for solutions, because most of the silica is in the form of quartz, are likely to be heavily silicified because of lack of bases and because solutions carrying silica down from source beds such as shale probably meet changed chemical conditions in the sandstone. Migration of water is less restricted in the sandstone and the dilution of incoming solutions is likely to change the pH value of the solution and thus lead to the precipitation of silica.

Occurrence of Opal.

Most of the silica transported and reprecipitated within the profile becomes an opaline impregnation or a cement to produce "porcellanite" or billy - materials which will not normally provide pure opal, unless in microscopic grains. The pre-requisite for the formation of opal in relatively large bodies is therefore the occurrences of voids in which opal can be precipitated without contamination by rock material.

A review of many of the past and present opal fields provides the following summary of the occurrence of opal -

1. In most places it occurs well down in the pallid, commonly 40-60 feet below the present remnants of mottled or ferruginous zone.

2. It occurs in -

   a. veins disposed at any angle, but commonly horizontal and parallel to bedding in many places;

   b. as the kurnel of concentrically formed boulders or nodules of billy - particularly found in some old Queensland fields;

   c. in cracks in boulders of billy (Hayricks Mine, Queensland);

   d. in the interstices of conglomerate or as a film on conglomerate boulders (Andamooka, S.A.).

3. In most places, opal is associated with sandstone rather than with shale or clay.

4. Opal is commonly found at definite horizons within the sediments.

It seems fairly clear from this evidence that the openings or voids needed for the formation of opal were supplied mainly by cracks or by openings or voids along beds from which a significant proportion of the rock material had been removed by leaching. In such beds opal formed in veins or lenses or as a core about which a concretionary boulder developed. Opal is commonly found in sandstone because sandstone is more competent than shale and voids or openings are more likely to persist. The opal is found on definite horizons within the sediments because, in most places, it is dependent on certain horizons, e.g., a calcareous sandstone, to provide the conditions necessary for its formation. Finally, opal is normally found in the lower portions of the lateritic profile because beds of sandstone in or near the mottled zone are in many places heavily silicified.

Prospecting for Opal.

It must be admitted that enquiry into the origin of opal in the Australian opal fields has produced little information likely to be of value in establishing opal prospecting on a firmer basis.

The dominant factors in the distribution of known opal fields are -

1. A mature lateritic profile developed on sub-horizontal* alternating beds of shale and sandstone.

2. Moderately deep dissection of the profile to expose a large part of the pallid zone.

Most of the known opal fields are associated with sediments of the Eyrian Series or those of the Cretaceous formations, but knowing the conditions under which opal is likely to form, it should be possible to delineate other regions in Australia in which deposits of opal may occur. Discussion of these prospects will be attempted in the full report.

Within the region in which the Eyrian Series and the Lower Cretaceous sediments outcrop it is possible that a study of the geological sequence may provide some information on the likelihood of finding deposits of opal in outcrops and in areas which have been little prospected. Cape Yorke Peninsula in Northern Queensland appears to be one little prospected area. Lateritised Cretaceous sediments outcrop over a wide area, and Jackson (1902b) record veins of common opal in this formation in the Moreton area.

The limits of the Eyrian Series are comparatively well known, but geological and palaeontological work over the past three years has proved a wide distribution of Lower Cretaceous sediments - particularly in the Northern Territory - and it is possible that this work may eventually indicate further areas where deposits of opal are likely to occur.

Unfortunately, the Lower Cretaceous sediments (Mullaman Group) outcropping in the northern portion of the Northern Territory are, in most places, very thin and composed almost entirely of shales. Common opal has been found by D.M. Traves in a lateritic profile developed on Lower Cretaceous sediments near Newcastle Waters in the Northern Territory but the laterite is not deeply dissected in that area, and there are no other localities which, at present, appear likely to contain deposits of opal.

L. C. Noakes

Geologist.

---

* It is possible for opal to form from lateritisation of steeply dipping beds but such occurrences are likely to be much more restricted than in horizontal beds.

REFERENCES.

Andrews, E.C., 1925 : Geology of the Lightning Ridge (Wallangulla) Field. Ann. Rep. Dept. Mines N.S.W. for 1924, p.85.

Clarke, F.W., 1924 : The Data of Geochemistry. United States Geol. Surv. Bull. 770. p.486.

Crespin, I., 1948 : Micropalaeontological Report on Rock Samples from the Opal Fields at Andamooke and Coober Pedy, South Australia Bur. Min. Res. Geol. and Geophys. Rep. No. 1948/55, unpubl.

Cribb, H.G.S., 1948 : Opal Deposits and the Hayricks Opal Mine, Quilpie. Q'ld. Govt. Min. Journ. 49, No. 556.

Croll, I.C.H., 1948 : The Opal Industry in Australia. Bur. Min. Res. Geol. and Geophys. (Mineral Economics Section) Rep. No. 1948/99. Unpubl.

Jackson, C.F.V., 1902a: The Opal Mining Industry. Geol. Surv. Q'ld. Rep. No. 177.

Jackson, C.F.V., 1902b: Report on a Visit to the West Coast of the Cape York Peninsula. Geol. Surv. Q'ld. Rep. No. 180, p.10.

Kellogg, C.E., 1943 : The Soils that Support Us. Macmillan, New York, p.83.

Noakes, L.C., 1947 : Geology and Mineral Resources of the Northern Portion of the Northern Territory. Bur. Min. Res. Geol. and Geophys. Rep. No. 1947/40. Unpubl.

Noakes, L. C. and Traves, D. M., 1949 : Terminology of Lateritic Profiles. Bur. Min. Res. Geol. and Geophys. Rep. No. 1949/26. Unpubl.

Stewart, G.A., 1947 : Report on Reconnaissance of the Soils of the Katherine-Darwin Region. North Australia Regional Survey (Preliminary report. Unpubl.).

Van Bemmelen, R.W., 1941: Origin and Mining of Bauxite in Netherlands-India. Soc. Econ. Geol. 36, (6) p.639.

Ward, L.K., 1916 : The Stuart's Range Opal Field. S.Aust. Min. Review No. 258.

Whitehouse, F.W., 1940 : Studies in the Late Geological History of Queensland. Univ. Q'ld. Dept. Geol. Papers 2, (1)

Woolnough, W.G., 1927 : The Duricrust of Australia. Roy. Soc. N.S.W. 61, pp. 24-53.