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THE STRUCTURE OF THE NORTHERN TERRITORY IN RELATION TO MINERALIZATION.

by

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THE STRUCTURE OF THE NORTHERN TERRITORY

WITH RELATION TO MINERALIZATION.

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INTRODUCTION.

The Northern Territory is an integral part of the great Australian Pre-Cambrian shield which underlies almost the whole of Western Australia and the Northern Territory, much of South Australia and portions of New South Wales and Queensland.

In most parts of the Continent, Pre-Cambrian rocks were welded into a stable shield before the end of Pre-Cambrian time, and in the Northern Territory itself the structural framework was established, and most of the mineral deposits introduced by an orogeny which terminated geosynclinal sedimentation about the end of the Lower Proterozoic. *

In Upper Proterozoic time and in subsequent eras, the Northern Territory behaves as a stable block, although it yielded, to some extent, to recurrent earth stresses by warping and faulting. There was, however, a total absence of the geosynclinal troughs which, in Eastern Australia, provided the environment for thick sedimentation and for subsequent folding and mineralization in Palaeozoic time.

In consequence, sedimentation in the Northern Territory since Lower Proterozoic time has been entirely of epi-continental character, with three great transgressions - in Upper Proterozoic (Nullagine), Middle Cambrian and in Lower Cretaceous time - when shallow seas flooded the greater part of the region.

Sedimentation in more restricted areas occurred in Palaeozoic time in the Bonaparte Gulf Basin, 180 miles south of Darwin, and toward the end of Pre-Cambrian time, in the down-warp which developed in the Arunta Block (see Plate 1), but although some of these sediments were folded and faulted by Lower Palaeozoic movements, they were not intruded by igneous rocks and were not mineralized.

A discussion of the structure of the Territory in relation to mineralization, therefore, is concerned mainly with Pre-Cambrian, and in particular with Lower Proterozoic rocks. Only a broad outline of the subject can be given here.

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* 'Lower Proterozoic' is used in the sence of David (1932). The Pre-Cambrian succession in Australia has been divided into three units, and commonly referred to as Kalgoorlie-Yilgarn, Mosquito Creek, and Nullagine, from type regions in Western Australia. Pre-Cambrian time has been divided into the Archaeozoic and Proterozoic Eras and David (1932) places the oldest rocks - Kalgoorlie-Yilgarn - in the Archaeozoic, Mosquito Creek in the Lower Proterozoic and Nullagine in the Upper Proterozoic. The writer, therefore, uses 'Lower Proterozoic' as the equivalent of Mosquito Creek time. Explanation is necessary because in Western Australian practice, both Kalgoorlie-Yilgarn and Mosquito Creek are placed in the Archaeozoic Era and only Nullagine in the Proterozoic Era (Clarke, Prider and Teichert, 1944). Browne, editor of David (1950) has replaced 'Archaeozoic' and 'Proterozoic' by Lower, Middle and Upper Pre-Cambrian.

Plate 1, showing the distribution of mineralized and unmineralized rocks in the Northern Territory and the writer's interpretation of the structural framework, from the date available, has been compiled from published and unpublished surveys by the Bureau of Mineral Resources,* from mosaic maps from aerial photographs and from data provided by previous literature, particularly the reports of the Aerial, Geological and Geophysical Survey of Northern Australia.

THE STRUCTURAL FRAMEWORK.

Interpretations of the structure of the Australian continent have been presented by David (1911, 1932), Cotton (1930), Bryan (1932), Andrews (1937), Hills (1947) and Fairbridge (1950) but the interpretation of the structure of the Northern Territory has always presented special difficulties because of the scarcity of detailed geological information. Most writers have based their interpretations of the structure of the Pre-Cambrian rocks of the Territory on the position of nuclei indicated by known or assumed trends of folding and the interpretations differ according to the amount of geological data available at the time.

The relative distribution of Archaeozoic and Proterozoic rocks appears fundamental to an interpretation of structure, and until a sufficient number of age determinations by radioactivity are available, the distribution in the Territory must be determined largely by degree and character of metamorphism although, admittedly, such a criterion must be used with care.

The most metamorphosed rocks in the Northern Territory are the paragneisses, schists and granite-gneisses of the Arunta Complex and the schists of the Musgrave Range (Arunta Block, Plate 1). The degree of metamorphism in these rocks is not only higher and the folding more severe than elsewhere, but these features are much more consistent than those observed in other pre-Nullagine rocks in the Territory. There is therefore reason to believe that they are the oldest rocks in the Territory and of Archaeozoic age.

The pre-Nullagine rocks of the Darwin and Tennant Creek regions and those along the western and southern shores of the Gulf of Carpentaria consist mainly of slate, quartzite, sandstone, shale and limestone with phyllite and schist developed in some places. They show a wide range in metamorphism but appear to be normal products of sedimentation in geosynclines or, in places, on continental shelves. The higher grades of metamorphism and deformation accompanying synchronous granites, for instance in the western portion of the Darwin region, are more comparable with those of some Lower Palaeozoic rocks in Eastern Australia rather than with those commonly found in the Arunta Block. Sediments showing lower grades of regional metamorphism, as in the eastern portion of the Darwin region, are commonly associated with granitic intrusives which are not of the synchronous type.

These rocks are therefore regarded as Lower Proterozoic - deposited and folded within the interval of time between the end of Archaeozoic and the beginning of Upper Proterozoic (Nullagine) time. Pre-Cambrian rocks with the same general range in lithology and metamorphism are found in areas adjacent

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* Unpublished field data from A. A. Opik, D. M. Traves, K. A. Townley, J. F. Ivanac, G. F. Joklik, and the writer.

to the Territory, in Queensland and Western Australia (Plate 1), and with the exception of a narrow belt of gneiss in Western Queensland, which may be of Archaeozoic age, these rocks may also be regarded as Lower Proterozoic.

This subdivision of Pre-Cambrian rocks in the Territory is in accordance with that suggested by Browne, editor of David (1950) but Browne regards some of the rocks in the Kimberley area as Archaeozoic.

From the distribution of folded Lower Proterozoic rocks, part of the structural framework can be outlined by tracing the mountain chains which arose from the geosyncline of Lower Proterozoic time. Roots of such ranges, marked by synchronous batholiths and highly metamorphosed sediments, are clearly exposed south of Darwin, in the Kimberley region and in Western Queensland. In other areas, such as at Tennant Creek and around the shores of the Gulf of Carpentaria, the fold-mountains suffered less uplift and consequently less erosion but the orientation of the rising mountain chains is clear. This, in turn, indicates the trend of three geosynclines which are referred to as the Pine Creek, Warramunga and Carpentaria Geosynclines. (See Plate 1).

These geosynclines were in foci of sedimentation in Lower Proterozoic time and their position and, in places, the trend of the folding subsequently impressed on the sediments, give some indication of the position of massifs or blocks of Archaeozoic rocks which provided the source of Lower Proterozoic sedimentation and also the relatively stable "forelands" and "backlands" in periods of orogeny. Three stable blocks - Kimberley, Sturtian and Arunta - composed essentially of Archaeozoic rocks, are therefore postulated in the Northern Territory and in adjacent areas in Western Queensland and Western Australia, although Archaeozoic rocks are believed to outcrop on only one of them - the Arunta Block.

The Kimberley Block (Plate I) is essentially the Kimberley Massif of Cotton (1930) and Kimberley Nucleus of Hills (1947) and the Sturtian Block stems from "Stuartiana" of Andrews (1937) and the Sturtian Nucleus of Hills (1947).

Much of the detailed history of these Proterozoic geosynclines could probably be worked out by detailed mapping aided by age determinations but at present the relative age and duration of sedimentation within the three geosynclines and the tectonic history of the Lower Proterozoic in this region is not known.

The major orogeny which terminated Lower Proterozoic sedimentation and led to final folding and uplift can reasonably be correlated with the Algoman revolution of North America, but detailed work may provide evidence of previous orogenies. Stille (1944) believes there were two orogenies of moderate intensity between the Laurentian and Algoman revolutions.

However, if Lower Proterozoic sedimentation occupied the entire interval between the Laurentian and Algoman revolutions, it would have persisted for about 275 million years, which is less than Palaeozoic time (about 310 million years) and not much more than the time interval represented by geosynclinal sediments (Cambrian, Ordovician and Silurian) in the Tasman Geosyncline in Eastern Australia, some 190 million years.

The rocks exposed in each of these three geosynclines show a wide range of metamorphism from granitized schists to almost unaltered sediments, and a range in intensity of folding from isoclinal to gentle dome and basin folds. The degree of regional metamorphism and the character and intensity of folding appear to be largely functions of the depth to which the orogens have been eroded, because, so far, no major unconformities have been observed within the sedimentary successions. Moreover, some of the sediments, still un-eroded, were apparently deposited on the shelf of the stable blocks where folding was less intense. Sediments around the south-western shores of the Gulf of Carpentaria appear to be examples of this, although in this region the area mapped as Lower Proterozoic probably includes some Upper Proterozoic (Nullagine) sediments which have yet been differentiated. Sediments of the Ashburton, Murchison and Davenport Ranges, in the area covered by the Warramunga Geosyncline, also appear to be epi-continental deposits. Some of these epi-continental deposits could represent sedimentation between Mosquito Creek and Nullagine time (in lower Upper Proterozoic time?) as previous workers have suggested for the rocks of the Murchison and Davenport Ranges (Nye 1941, Sullivan 1946), but there is so far insufficient evidence to prove or disprove this hypothesis.

However, it is fairly clear that the orogeny about the end of Lower Proterozoic time provided the major forces to complete the welding of the Pre-Cambrian rocks of the Northern Territory. Geosynclinal sedimentation, in this region, ended for all time and the rising of new mountain chains and the sinking of stable blocks ushered in Upper Proterozoic time which in the Northern Territory, is predominantly the history of the erosion of these mountain chains, and the deposition of the resulting sediments in epi-continental seas.

MINERALIZATION IN THE NORTHERN TERRITORY.

Ore deposits in the Territory can be divided into three main groups. The most important group by far contains the hydrothermal ore deposits and the pegmatites of the Lower Proterozoic rocks; deposits introduced by mineralization accompanying an orogeny or orogenies in Lower Proterozoic time.

The second group which is of less economic importance, consists of mineral deposits found in the Arunta Block. These are largely contained in pegmatite dykes and, in most places, appear to be a result of mineralization in Archaeozoic time.

The third group is only of minor importance and consists of a few deposits of copper and silver-lead which occur in Upper Proterozoic or Cambrian rocks. These deposits have no connection with earlier hydrothermal mineralization and, in most places, are too small to warrant development.

Geological investigations in the Territory have shown that the zones of highest metamorphism, - towards the roots of the Lower Proterozoic orogens and in the Arunta Block - have provided little in the way of mineral deposits apart from those contained in pegmatite dykes, and that nearly all important deposits are the result of hydrothermal mineralization at moderate depths within the Lower Proterozoic orogens.

MINERAL DEPOSITS OF THE LOWER PROTEROZOIC ROCKS.

Pine Creek Geosyncline.

Within the Northern Territory, mineral deposits of the

Pine Creek Geosyncline are restricted to the Darwin region.

The deposits may be divided into two groups - deposits found in pegmatite dykes in the western portion of the region, and hydrothermal deposits of gold, tin, copper, wolfram, silver-lead and uranium which occur in the central and eastern portions of the region (Noakes, 1949).

Deposits of tin and tantalite in pegmatite and greisen dykes are associated with a great synchronous batholith - the Litchfield Granite - in the western portion of the Darwin region. Pegmatite dykes and pipes occur mainly in quartzites, phyllites and schists along the eastern border of the Litchfield Granite where the sediments have been severely folded. Granitization of the sediments is apparent in places, and the general grade of metamorphism is fairly high. Small deposits of gold and silver-lead in quartz veins, and of copper in shear zones or as replacements, have also been found in the pegmatite zone in the southern-western portion of the region.

In the central and eastern portions of the region a variety of mineral deposits occur in sandstone, quartzites, slates and tuffs in which the grade of regional metamorphism is noticeably lower and the folding less intense than that found in the western portion of the region. The principal mineral deposits are those of gold, tin, copper, wolfram, silver-lead and uranium. Most of these deposits are associated with a subsequent batholith - the Cullen Granite - or with smaller bodies of granite, most of which show sharp contacts with the sediments. Some of the smaller bodies are concordant where they occur in folds within the sediments but, in most places, the contacts are sharp with little granitization.

In general, the mineral deposits are small, although the tin deposits at Maranboy and the gold ore at the Cosmopolitan Howley Mine are extensive. Much of the gold, tin and wolfram production has been obtained from quartz reefs, although auriferous deposits, replacing tightly folded beds, are of common occurrence. In the Brock's Creek district, in the central portion of the region, several deposits of copper and gold are found within the same formation and appear to be associated with sills of amphibolite (Sullivan, 1947). In places, quartz veins containing tourmaline, wolfram and cassiterite occur close to bodies of granite.

Warramunga Geosyncline.

Geological information is very incomplete over most of the area occupied by sediments of the Warramunga Geosyncline, mainly because of desert conditions and the scarcity of outcrops.

In most of the known outcrops, the grade of regional metamorphism is not high, although schists are found in places toward the southern limits of the sediments of the Warramunga Geosyncline where folding also appears to be more intense. Known outcrops of granite, with which most the mineralization is probably associated, are not of the synchronous type although they are concordant in places. Deposits of gold, wolfram, copper and bismuth have been found in several isolated fields. At Tennant Creek the rocks consist mainly of interbedded shale and sandstone which have been moderately folded and have been intruded by granite and porphyry. The degree of regional metamorphism is low.

Gold and bismuth with traces of copper and lead occur in quartz-hematite lodes which occupy crushed or faulted zones in the sediments. The mineralization is apparently genetically related to the porphyries.

At Wauchope, 78 miles south-east of Tennant Creek, wolfram-bearing quartz-veins occur in beds of shale which are interbedded with thick beds of sandstone and quartzite. Shale has been localy altered into hornfels. The beds have been folded into domes and basins and have been intruded by granite with which the mineralization is associated.

Quartz veins bearing wolfram and scheelite occur at Hatches Creek - 110 miles south-east of Tennant Creek. The veins occupy some of the many faults cutting a moderately folded sequence of quartzite, sandstone, shale and pyroclastic material. These rocks have been intruded by basic rocks but apart from two small bodies of porphyry, no acid intrusives have been found in the area.

At Barrow Creek, 80 miles south of Tennant Creek, copper orebodies occur in schist and sandstone which has been strongly folded and shows higher regional metamorphism than that observed farther north. The copper deposits appear to be associated with faulting and a discordant contact within the sediments.

Copper deposits in the Jervois Range, 250 miles south-east of Tennant Creek, occur in a moderately folded sequence of interbedded limestone, sericite schist, sandstone and slate. The grade of regional metamorphism appears to be comparable with that of the Barrow Creek area, but is noticeably lower than that found in the Archaeozoic rocks west of the Jervois Range. Copper and some lead minerals have replaced lenticular masses of garnetiferous limestone and calcareous shale.

In the western portion of the area occupied by the rocks of the Warramunga Geosyncline, auriferous lodes replacing beds have been found at The Granites and auriferous quartz veins occur at Tanami. The lode and veins occur in folded schist and quartzite and are associated with bodies of granite.

The Carpentaria Geosyncline.

Most of the known mineral deposits of the Carpentaria Geosyncline occur in Western Queensland, where copper, iron, gold and cobalt have been found in highly folded and fairly highly metamorphosed sediments in the eastern portion of the Mt. Isa-Cloncurry region. In the western portion of the region the principal deposits are those of lead-zinc and copper. Pegmatite dykes occur in the vicinity of the synchronous batholith south of Mt. Isa.

The only mineral deposits known in the Territory are small lodes of silver-lead and copper in the Macarthur River area, near the south-western corner of the Gulf, where limestones, shales and sandstones show a low grade of regional metamorphism and fairly gentle folding. No granite has been found in this area, but farther north, along the western shores of the Gulf, granite occurs in several places, and, judging by air photographs, the severity of folding increases. This part of the Territory is almost unknown geologically, and shows promise of mineral deposits. Traces of gold and copper have been reported but not confirmed.

The western side of the Carpentaria orogen constitutes a lead-zinc-copper province. A recent reconnaissance has suggested that, in general, the sediments are progressively older, more metamorphoses and more severely folded as one moves southward from the Territory through Western Queensland.* The deposits of silver-lead increase in size and importance in the same direction - from the small, telemagmatic(?) deposits of the Macarthur River area, which occur in little-metamorphosed sediments in upper levels of the orogen, to larger deposits at Lawn Hill, 160 miles north of Mt. Isa, and finally to the major replacement deposits of silver-lead-zinc and copper at Mt. Isa itself.

MINERAL DEPOSITS IN THE ARUNTA BLOCK.

In the Harts Range, 120 miles east of Alice Springs, commercial mica (muscovite), tantalite, and some radio-active minerals are found in pegmatites intruding Archaeozoic gneisses andcrystalline schists.

Nearly all of the commercial mica has been won from pegmatites intruding two formations and the most productive dykes transgress the foliation of the host rock.

Tin and tantalite occur elsewhere in the Arunta Complex and gold-bearing quartz veins occur in quartzite in the Arltunga area, 50 miles east of Alice Springs.

Hossfeld (1937) believes that these quartzites are part of the Arunta Complex but Joklik+ has found a marked unconformity between the quartzite at Arltunga and the underlying Arunta Complex and considers that the quartzite may be an outlier of Lower Proterozoic sediments.

DEPOSITS OF COPPER AND SILVER-LEAD IN UPPER PROTEROZOIC OR CAMBRIAN ROCKS.

Small deposits of copper occur in fault fissures in lavas at Wollogorang, on the Northern Territory-Queensland border, 40 miles south of the Gulf of Carpentaria. The age of these lavas is uncertain, but they may be Upper Proterozoic, in which case the mineralization is probably younger than that which gave rise to the lead and copper deposits of the Lower Proterozoic rocks.

Native copper occurs in lavas of Lower Cambrian age, 200 miles south-south-east of Darwin, but the deposit is not of economic importance.

A small deposit of silver-lead has been reported from Middle Cambrian dolomite or limestone near Morestone Station, about 100 miles north-west of Mt. Isa, but no details are yet available. Another recent discovery of silver-lead minerals in limestone has been made at Mainorou, 240 miles east-south-east of Darwin. The ore replaces sub-horizontal beds of dolomite or limestone which overlie basic lavas. The age of the limestone is probably Cambrian, as at Morestone, but the deposit at Mainorou is probably more extensive and may be of economic importance.≠

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* Unpublished field work - T. C. Noakes and D. M. Traves

+ Personal communication

≠ Unpublished field work - B. P. Walpole.

METALLOGENETIC EPOCHS.

Most of the mineral deposits of the Northern Territory - those occurring in the Lower Proterozoic sediments - were fairly clearly introduced in Lower Proterozoic time, mainly by granitic rocks which do not intrude Upper Proterozoic sediments. However, it is not yet possible to determine whether there was more than one metallogenetic epoch involved. Certainly it is reasonable to assume that a major metallogenetic epoch accompanied the major orogency which closed Lower Proterozoic time, although some mineralization would probably have accompanied any earlier Lower Proterozoic orogenies. Browne (1944) has already suggested that, with few possible exceptions, the mineral deposits of the Territory were introduced by the Houghtonian metallogenetic epoch, about the end of Lower Proterozoic or Middle Pre-Cambrian time. This can be correlated with the Cloncurry metallogenetic epoch of Jones (1947) in which he considers that the mineral deposits of Western Queensland were introduced.

It should be pointed out that Browne's exceptions related to deposits of wolfram at Wauchope and to deposits of lead-zinc at Lawn Hill, for he and others were obliged to consider Lower Palaeozoic mineralization as a possibility because some granites in the Warramunga Geosyncline were thought to be Cambrian and because mineralization at Lawn Hill occurred in sediments thought to be Cambrian. Recent field work* has shown that both granites in the Warramunga Geosyncline and sediments at Lawn Hill are Pre-Cambrian; thus the anomalies in these areas disappear.

However, the age of the pegmatite mineralization in the Harts Range is not definitely known. Browne (1944) assigns this mineralization to the Houghtonian Epoch, thus linking it with that of the Lower Proterozoic rocks. On the other hand, Sullivan and Joklik/ consider that these pegmatites were probably associated with the major orogeny which produced the schists, paragneisses and migmatites of the Arunta Complex and are therefore probably Archaeozoic.

The age of the gold mineralization in the quartzite at Arltunga is part of the same problem, because if the quartzite be regarded as Lower Proterozoic, the occurrence of some Lower Proterozoic mineralization in the Arunta Block is established, and Hossfeld (1937) who considered the quartzite as Archaeozoic, believes that the quartz veins in the quartzite and the pegmatite dykes in the Arunta Complex were of the same generation.

The age of mineralization in the third group of deposits - copper and lead deposits in Cambrian or Upper Proterozoic rocks - is still uncertain. Sullivan (1946) has suggested that copper mineralization at Wollogorang is possibly genetically associated with Lower Cambrian volcanic activity, although the lavas in that area are probably older than Cambrian. The age of the silver-lead mineralization in Cambrian limestone is even more obscure. Certainly there appears to be no connection between these deposits and the known metallogenetic epochs in the Northern Territory and, in other parts of the world, it is apparently difficult to correlate lead mineralization in limestone with known periods of orogenesis and igneous activity.

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* Unpublished field work - A. A. Opik, K. A. Townley

/ Personal Communication.

The evidence available suggests, therefore, that most of the mineral deposits in the Northern Territory were introduced in Lower Proterozoic time, largely by the Houghtonian metallogenetic epoch towards the end of that period, with the probability that one or more earlier metallogenetic epochs are represented in Arunta Complex. Sporadic mineralization in Upper Proterozoic and Cambrian rocks has yet to be proved of economic importance, so that eras since the Pre-Cambrian have added little to the Territory's metalliferous wealth. The main prospects for additional ore deposits in the future, therefore, lie in outcrops of Archaeozoic and, more particularly, in Lower Proterozoic rocks, and areas which are most likely to repay scientific prospecting are believes to be those occupied by the rocks of the Warramunga Geosyncline, the western shores of the Gulf of Carpentaria and the northern portion of the Darwin province.

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NORTHERN TERRITORY

STRUCTURAL FRAMEWORK AND METALLIFEROUS PROVINCES