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THE GEOLOGY AND MINERAL RESOURCES OF THE NORTHERN PORTION OF THE NORTHERN TERRITORY.

by

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Report No.1947/40.

I. SUMMARY.

1. A geological reconnaissance has been made of an area of approximately 27,000 square miles lying north and west of Katherine in the Northern Territory.

2. A new geological map has been compiled and an account of the stratigraphy and s summary of the economic geology has been prepared.

3. An attempt has been made to re-organise the classification and nomenclature of rock units in the northern portion of the Territory in accordance with the system adopted by the Bureau of Mineral Resources.

4. Sedimentary rocks of the region consist largely of folded Lower Proterozoic sediments which form the basement rocks of the region. These are overlain unconformably by arenaceous Upper Proterozoic sediments and these in turn are overlain by Lower Cambrian limestones and sandstones. An interval of erosion is suggested between Upper Proterozoic and Lower Cambrian sedimentation but the evidence is not conclusive.

5. Sedimentation took place during Palaeozoic time in the East Indies Geosyncline but this for the most part lay to the west of the Northern Territory and its sediments are represented in this region only by a narrow belt of Upper Palaeozoic rocks which occur along the western seaboard.

6. The greater part of the region remained a land mass from Cambrian to Late Jurassic or Early Cretaceous time. Sediments were then deposited in fresh water lakes and were eventually overlain by marine sediments laid down in a shallow Lower Cretaceous sea.

7. There is no record of younger sediments, and the region has remained one of comparatively low relief since Cretaceous time.

8. Extensive lateritisation occurred in Tertiary time and the porcellanite and the red lateritic rock found overlying Lower Cretaceous sediments are remnants of this Tertiary laterite profile.

9. Uplift by warping and faulting took place late in Tertiary time and initiated the present cycle of erosion. Laterites have formed during the present cycle of erosion and oscillations in sea level in Pleistocene and Recent time have lead to the formation of marine coastal plains and of extensive alluvial deposits along the lower courses of the major streams.

10. Igneous rocks consist of Lower Proterozoic amphibolites and granites which intrude the Lower Proterozoic sediments and of minor outcrops of volcanic rocks. Evidence for the age of the volcanics is not conclusive but all are believed to represent sporadic outbursts of volcanic activity in Lower Cambrian time prior to the deposition of the Lower Cambrian sediments.

11. Mineral production in the northern portion of the Territory reached a very low level in 1946 when the value of mineral production was approximately £1,346. This is due partly to the interuption of mining activity by World War II and partly to the fact that the established mineral fields at present offer few opportunities to miners and prospectors. Mineral production should increase in the immediate future but it will remain small and largely dependent on syndicate mining for some time.

12. There are no areas within the region in which a search for petroleum could at present be justified.

13. The region has a comparatively high rainfall and supplies of underground water are available at most places should they be required.

II. INTRODUCTION.

A. GENERAL.

From June to September, 1946 the writer was attached as Geologist to a party from the Council for Scientific and Industrial Research, which was engaged in a regional survey of part of the northern portion of the Northern Territory. The primary objects of the survey were to determine the pastoral and agricultural possibilities of the country, and the scientific personnel consisted of Mr. C.S. Christian, Ecologist and leader of the party, Mr. G.A. Stewart, Soil Surveyor, Mr.S.T. Blake, Botanist (on loan from the Queensland Department of Agriculture) and the writer.

The Geologist was attached to the party mainly because the area to be surveyed had been very incompletely mapped, and the existing geological records did not provide an adequate background for the soils and pastoral work to be undertaken. The primary function of the geologist was, therefore, to provide this background for soil interpretation, but it was also intended that he should gather as much information as possible on the stratigraphy and mineral possibilities of the area.

During the course of the investigation it was found that geological mapping provided an essential framework into which much of the other scientific data could be fitted and a fairly complete investigation of the stratigraphy and geomorphology of the area became essential. An account of the stratigraphy and geomorphology are submitted in this report with a reconnaissance geological plan of the region. This geological plan is the result of the combined work of the party and could not have been completed without the full co-operation of the other members and particularly of Mr. G.A. Stewart.

An area of approximately 27,000 square miles had to be mapped by a series of traverses in a period of approximately four months, and the geology of the areas between these traverses had then to be filled in from available geological maps and records and from aerial photographs which covered only parts of the region investigated.

Subsequent field work will probably show inaccuracies, due to incorrect interpolations or to faulty interpretation of air photographs, but the plan provides a fairly reliable picture of the regional geology and should form a useful basis for future geological work.

An attempt was also made to review the potentialities of the region in regard to mining, petroleum and underground water supplies and the results of this work are submitted in the economic section of the report.

B. GEOLOGICAL MAPPING.

The reconnaissance was carried out by a series of traverses made from a mobile base camp which moved every three or four weeks to suit the requirements of the survey party. In general, the technical members of the party worked together as one team so that technical problems could be discussed in the field. This combination of Ecologist, Botanist, Soil Surveyor and Geologist proved highly successful as each member benefitted from the technical knowledge of his colleagues.

The area is not well served by roads, but the party travelled in jeeps which provided access into trackless country and the total distance covered by these traverses was approximately 3000 miles.

Army Survey maps provided a basis for geological mapping and these were supplemented, in some areas, by aerial photographs. The Army maps consisted of an eight mile to 1 inch series which covered the entire area; a four mile series which covered approximately 65 per cent of the area and a one mile series, compiled from aerial photographs, which covered approximately 20 per cent of the area. The route of each traverse was plotted in the field onto aerial photographs or onto the largest scale map available. Spot heights were taken by barometer and corrected, as far as possible, from barographs made from regular barometer readings taken at the base camp. Where the maps lacked adequate topographic detail the route was plotted by compass traverses, using the speedometer and an aerial compass mounted in one of the vehicles. Geological data was plotted onto the maps or photographs as the traverse progressed and transferred to a master plan on return to the base camp.

The topographical accuracy of both eight mile and four mile maps was generally poor, but few corrections or additions, beyond those of salient features, could be made during the reconnaissance.

The geology of the areas lying between the traverses had then to be filled in from aerial photographs or from previous records and, where these were lacking, by interpolation. The greater part of this work was carried out jointly by Noakes and Stewart at Canberra, where a master plan was assembled on a scale of four miles to one inch.

Geological boundaries established in the field or by stereoscopic examination were marked on the vertical photographs and then transferred to the master plan by principal point plot. Geological boundaries were also plotted on some of the oblique photographs from trimetrogon runs and transferred to the plan. The photographic runs were oriented and the information transferred by means of the system of co-ordinates carried on the military plans. These co-ordinates were retained on the geological map to allow localities to be accurately indicated by six figure references. The completed geological plan and sections were then reduced by photography to a scale of 8 miles to 1 inch which was adopted as the scale of the final plan.

Photographs covering every aspect of the reconnaissance, were taken by C.S. Christian, and a number of them have been selected to illustrate the technical reports. These photographs appear in a separate folder and reference to those of geological interest will be found in the text of this report.

III. TOPOGRAPHY.

The region lying north and west of Katherine may be described as a maturely dissected tableland with a maximum relief of approximately 1,000 feet. Remnants of the original tableland still exist in the form of isolated flat-topped hills along the main divide and more extensive residuals are found in the Arnhem Land Plateau and in the tablelands south of the Daly River.

The main divide runs in a north-westerly direction through the centre of the region but swings to the north at the head of the Adelaide River. The topography, in general, is mature and in consequence the divides between the principal watersheds are rarely well defined. The three principal topographical divisions are those of the northern plains, the western plains and the Daly River basin.

The northern plains lie between the main divide and the northern coastline and comprise a great area of flat or very gently undulating country which extends from the railway line northward to the sea. In the central portion, the railway line lies approximately 80 miles from the coast but the average elevation is little more than 300 feet. The streams flowing northward from the main divide soon lose any semblance of youth and are mature or senile over most of their course. The northern plains are bounded on the south by foot hills which lead back to the main divide on which isolated mesas attain an elevation of 900 to 1000 feet above sea level. To the east the plains are bounded by the Arnhem Land Plateau and to the west they are separated from the western plains by a series of low ridges which rarely exceed 400 feet in elevation.

The western plains extend inland from the western coastline for distances up to 60 miles where they terminate abruptly against prominent north-south ridges. The Daly River traverses these plains for some 50 miles from the ridges to the sea and its flow is subject to the tides over the whole of this distance. Large areas of these plains drain inwards into swamps, and rivers, like the Reynolds, have no permanent channels connecting them with the sea. The southern limit of the plains is an irregular boundary formed by tablelands which constitute the divide between the Daly and the Fitzmaurice Rivers.

In its upper reaches the Daly River Basin has been formed in comparatively soft, horizontal strata. The broad shallow basin is about 180 miles long and 90-100 miles wide and the topography here, though generally undulating, has not reached the same stage of maturity as found on the northern and western plains. The Daly River and its tributaries are still actively eroding a series of low horizontal bars of more resistant strata over which the rivers pass in rapids or falls. The Daly River Basin is bounded by the main divide on the north and by an incised tableland to the south, but to the east it merges gradually into the mature upland country south of Katherine.

IV. GENERAL GEOLOGY.

A. INTRODUCTION.

The Northern Territory forms part of the Australian Pre-Cambrian Shield and has been a comparatively stable area since Pre-Cambrian time. With the exception of the western seaboard, the country to the north and west of Katherine contains the record of only two periods of submergence since the Pre-Cambrian - one during Lower Cambrian and one during Lower Cretaceous time. There is no record of major diastrophism since the Pre-Cambrian era and this long period of comparative stability and practically uninterrupted erosion has produced a region of low relief which consists, for the greater part, of Pre-Cambrian rocks.

The record of sedimentation includes Older and Younger Pre-Cambrian rocks, Lower Cambrian sediments and a veneer of Lower Cretaceous deposits. A geosyncline developed to the west of this portion of the Territory during Palaeozoic time and the western coastal area consists mainly of Permian sediments deposited near the eastern margin of the trough.

The Older Pre-Cambrian sediments have been folded and metamorphosed but there is little folding or metamorphism in the Younger Pre-Cambrian rocks or in any of the subsequent sedimentary deposits, although there is evidence of a series of vertical movements. The only known igneous intrusives are the Pre-Cambrian amphibolites and granites which intrude the Older Pre-Cambrian sediments. The absence of younger igneous intrusives is a further indication of the stability of the area since Pre-Cambrian time. Volcanic rocks occur in several places but all appear to belong to the Lower Cambrian when volcanic activity was widespread.

B. NOMENCLATURE.

The nomenclature of rock units has presented a problem in preparing an outline of the geology of the region. Much of the existing nomenclature was confusing, partly because earlier workers had not followed a definite system in naming units and partly because some units had not received formal names. An attempt has been made to organise nomenclature of the northern portion of the Territory by following the system of classification and nomenclature of rock units adopted by the American Association of Petroleum Geologists and by the United States Geological Survey (Bartrum 1936). This system is widely used in America and has been adopted by the Bureau of Mineral Resources, Geology and Geophysics.

In attempting to organise nomenclature of rock units in the Northern Territory all the formation names appearing in earlier records have been retained, although the classification of the unit has, in some cases, been changed in accordance with the rules of the system adopted. Since geological data is still very incomplete the suggested nomenclature is intended to form only a framework into which future workers can conveniently build.

This suggested system is set out in the accompanying stratigraphical table (Table I.) and the principal changes which have been made are discussed in the following notes.

1. Lower Cretaceous.

The beds were mapped as Jurassic by Geologists of the Aerial, Geological and Geophysical Survey of Northern Australia in 1936, (Voisey 1939a) but were not formally named. Earlier workers assigned them to different ages and termed them Plateau sandstones but no formal names were applied. The full stratigraphical interval represented by these beds is not known and they probably include conformable Jurassic sediments at the base. They have a wide distribution and warrant classification as a group rather than as a formation.

It is difficult to find a suitable formal name since few of the mesas which the group characteristically forms, have names, but the Mullaman Group is suggested after the Mullaman Tablelands 5 miles west of Pine Creek, where fairly typical sections of these beds were described by Rev. Tenison Woods in 1886. The name Darwin cannot be applied to the group as only the upper portion is represented in that locality.

The Mullaman Group can be sub-divided into an upper part consisting of shales and a lower part consisting mainly of sandstones with some conglomerates. The shales are well developed in the Darwin area and the name Darwin formation is therefore proposed for these beds but further sub-division of the group is left for future workers.

2. Permian.

Sediments of Permian Age were identified by

Commander Stokes near the mouth of the Victoria River in 1886 and were subsequently found to continue northward along the coast to the Daly River. However no formal name or classification has apparently been adopted for these beds and the Port Keats Group is suggested. Portion of the Group is exposed in the cliffs at Port Keats and boring in this vicinity has provided details of the stratigraphical succession over an interval of 730 feet (Browne 1906).

3. Upper Palaeozoic.

A formation of Upper Palaeozoic rocks has been mapped by the writer to the north of Mount Litchfield in the western portion of the region but their relationship to the Permian strata on the western coast has not been established. Palaeontological evidence is inconclusive but suggests that these rocks which include sandstones, shales and limestones are either Devonian or Permian in age. These sediments have been named the Elliott Creek formation, after Elliott Creek which drains much of the area in which they outcrop and their relationship to the Port Keats Group, of which they may form a part, could not be determined during the present survey.

4. Cambrian.

The only formal name given to Cambrian sediments in the past is that of the Daly River Limestones (Voisey 1939a), applied to limestone, shale and sandstone beds in the Daly River area. Recent observations suggest that the Cambrian sediments may be divided into two units - a lower consisting of limestone, shale and sandstone and an upper consisting dominantly of sandstones. These two units should be classified as groups rather than formations as subsequent work will probably enable further sub-division on both lithological and palaeontological grounds to be made. The name Daly River Limestone Group is proposed for the lower and Florina Group (after Florina Station) for the upper unit.

5. Volcanic Rocks.

Volcanic rocks have been found at Edith River, Maude Creek and in the Collia Creek area and have been referred to as volcanic series (Voisey 1939a). These rocks include lavas and pyroclastics and may rightly be termed Volcanics in the new system of classification. These rocks are therefore referred to as the Edith Creek Volcanics, the Maude Creek Volcanics and the Collia Creek Volcanics. Separate names have been retained for the various outcrops of these rocks because the evidence for consanguinity is not sufficiently conclusive for them to be mapped as one unit.

6. Upper Proterozoic.

The sandstones and quartzites of Upper Proterozoic age have been named the Buldiva Quartzites in the south-western part of the region by the Aerial, Geological and Geophysical Survey of Northern Australia (Voisey 1939a). This name is therefore retained, although the rank of the unit has been changed from formation to group. These beds are approximately 200 feet thick in the Buldiva area but in other places they are probably several thousand feet in thickness and represent a significant period of sedimentation in Upper Proterozoic time. Because of similarity in age, structure and lithology they are, tentatively correlated with the Nullagine series of Western Australia.

1. Lower Proterozoic.

a. Granitic Intrusives - There are many outcrops of granite in the region but formal names are suggested only for the two major intrusives. The larger of these lies west of Mount Tolmer and has been named the Litchfield granite after Mount Litchfield where typical outcrops of the granite are found. The eastern intrusive, which outcrops over a wide area east of Pine Creek, has been named the Cullen granite after the Cullen River which lies entirely within the area occupied by the granite.

b. Brocks Creek Series - A great deal of detailed mapping will be required before the folded Lower Proterozoics can be sub-divided but the work which has been done suggests that there are no unconformities within these beds. A classification of these rocks into three groups was suggested by the Aerial, Geological and Geophysical Survey of Northern Australia (Voisey 1939a) and the names Golden Dyke Series, Pine Creek Series and Muldiva Series were applied. However, until the age relationships of these three subdivisions can be established it is preferable to regard them as Groups and the whole sequence as a Series. It is therefore suggested that all of these rocks be regarded as the Brocks Creek Series with possible sub-divisions into the above-mentioned three Groups. The name Pine Creek might have been more appropriate for the Series but this has been used for a sub-division and should therefore be retained as such. Sub-divisions of the Pine Creek Group were also suggested by the Aerial, Geological and Geophysical Survey of Northern Australia but as detailed mapping could not be undertaken during the present survey the further sub-division of the Brocks Creek Series is left for future workers.

C. STRATIGRAPHY.

1. Lower Proterozoic.

a. The Brocks Creek Series. The Brocks Creek Series constitutes the basement rock of the northern portion of the Territory and outcrops over the greater part of the region lying north and west of Katherine. The Series consists of folded and intruded geosynclinal deposits which originated as sandstones with occasional conglomerates, tuffs, shales and unfossiliferous limestones. These have since been converted by regional metamorphism into silicified sandstones and tuffs, quartzites, slates and phyllites. In general the grade of the regional metamorphism is surprisingly low. Silicified contact metamorphic rocks including hornfels and chiastolite slate are found in proximity to the igneous intrusives.

The Series is estimated by the Aerial, Geological and Geophysical Survey of Northern Australia (Voisey 1939a) to exceed 15,000 feet in thickness and has been divided into three Groups. No unconformities have so far been noted anywhere in the considerable thickness of sediments. The Golden Dyke Group, which is apparently the youngest, consists of sandstones, conglomerates, quartzites and slates with a total thickness of over 2,000 feet. The Group is intruded by thin sills of amphibolite. The Pine Creek Group consists of slates, sandstones and tuffs, and the Muldiva Group comprises quartzites, phyllites and schists. However, the Muldiva Group may represent a more highly metamorphosed phase of the Pine Creek Group. The folding of the Golden Dyke Group appears more open than that shown elsewhere in the Series but this probably reflects differences in the competency of strata and, perhaps, in depth of burial. The strike of the Series is consistently close to meridional over very wide areas although dome and basin structures are common in the Golden Dyke Group.

The distribution of these three Groups has not been determined but the Golden Dyke Group outcrops mainly between Adelaide River and Grove Hill along the railway line and extends south to the northern edge of the Cambrian sediments and north for at least 15 miles. The Pine Creek Group, as the name suggests, is typically developed in the Pine Creek area but it may comprise nearly all the remaining outcrops of the Brocks Creek Series. The sandstones and slates west of Adelaide River and south-west across the Daly River appear to belong to this group, but further to the west and south the grade of metamorphism noticeably increases and phyllites, quartzites and mica schists of the Muldiva Group are found along the Finniss River and near Fletcher's Gully to the south of the Daly River.

There is strong evidence that regional metamorphism increases west of Adelaide River and the lower grade metamorphics grade into schists and schistose sandstones which occupy a meridional belt whose eastern margin runs roughly from Buldiva through the Daly River Police Station to Rum Jungle on the Railway line. This zone of intense regional metamorphism was subsequently intruded and the Litchfield granite now forms the western boundary of the schistose rocks.

The Brocks Creek Series appears much younger than the Archeozoic rocks of the Arunta Series found in other parts of the Northern Territory and may be correlated with the Mosquito Creek series of Western Australia. The higher grade metamorphic rocks found in the Finniss River area might be mistaken for older sediments but there is no evidence to suggest that they are unconformable with the metamorphics of the Brocks Creek Series to the east.

<u>b. Granitic Rocks</u>. Granitic rocks are widely distributed over the region. They intrude the Brocks Creek series but are older than the Buldiva Group and are therefore regarded as Lower Proterozoic. There are two major areas of granite - one in the east and one in the west and many smaller outcrops. The major intrusives have been named the Cullen granite in the east and the Litchfield granite in the west, but no formal names are proposed for the smaller intrusives.

The major intrusives are essentially similar in mineral constitution and there appears to be no evidence to suggest that they belong to different intrusive epochs. The most common type is a medium-grained biotite-hornblende-granite in which hornblende constitutes only a small percentage of the ferro-magnesium minerals. Marginal phases are commonly porphyritic in quartz, biotite or felspar and more basic dioritic phases are found in some places. Some marginal phases show directional structures but in general there is little evidence of gneissic foliation.

The Cullen granite is elongated in a north-south direction but it does not conform closely to the structures of the Brocks Creek Series. The contacts between the Cullen granite and the Brocks Creek series are fairly sharp. Contact metamorphic types such as hornfels are commonly found but no extensive granitisation was observed. Pegmatites and quartz veins carrying tin and wolfram are found in some contact areas, but high temperature mineralisation does not appear to be as extensive as that associated with the Litchfield granite.

The Litchfield granite is the larger of the two major intrusives although a great part of it is now masked by Palaeozoic and Recent sediments. It forms a long meridional area of outcrop conforming with the structural trends of the Brocks Creek Series. The eastern margin is well defined and the western boundary is exposed in the vicinity of Fog Bay but is masked to the south. The Litchfield granite has been traced for 100 miles in a north-south direction and is at least 30 miles wide in the vicinity of the Daly River. Although petrologically similar to the Cullen granite, the Litchfield granite seems to have been intruded under conditions of higher stress, perhaps consequent on deeper burial. The aureole of metamorphic rocks shows a higher degree of regional metamorphism than found elsewhere in the region and the granite itself shows directional structures in some contact areas. Granitisation of the intrused rock has also taken place and this is well shown by the granitised schists found on the foreshores of Bynoe Harbour. High temperature mineralisation is common along the eastern margin where tin-and tantalite-bearing pegmatites and greisen occur.

The smaller granitic intrusives are petrologically similar to the Cullen and Litchfield granites and are believed to be genetically associated with them.

2. <u>Upper Proterozoic</u> - The Buldiva Group.

<u>a. General</u>. The Buldiva Group was first recognised by the Aerial, Geological and Geophysical Survey of Northern Australia in the area between Buldiva and Reynolds River, (Voisey 1939a), but few other exposures were recorded. During the recent reconnaissance the Mount Tolmer Plateau was found to consist of sub-horizontal sandstones and quartzites of the Buldiva Group and a considerable extension of these beds north of Blackfellows Creek has been traced on aerial photographs. The outcrop of the Group is very distinctive in aerial photographs, particularly where the dips are low, and there seems little doubt that the greater part of the Arnhem Land Plateau, which stretches from Katherine to the coast east of the Alligator River, is composed of gently dipping strata of the Buldiva Group. Outliers of this Group, faulted into the Brocks Creek Series, have also been identified in air photographs between Burrundie and the Arnhem Land Plateau. Another faulted outlier of the group occurs along Hayes Creek, south of the Stuart Highway (Map reference 455/270). Part of this outlier was mapped by the Aerial, Geological and Geophysical Survey of Northern Australia in 1939, but the map has not been published. An unconformity with the underlying Brocks Creek Series was recognised and the quartzite outlier was mapped as Nullagine. This quartzite shows a higher degree of silicification than is usual in the Buldiva Group but the outcrop abuts against a major fault and may have been silicified by solutions from that channel.

In the outcrops exposed on Mount Tolmer and at Blackfellow's Creek the Buldiva Group consists mainly of sandstones and quartzites with some beds of grit and shale. The sandstones and quartzites in most places show abundant evidence of shallow water deposition in the form of beautifully preserved ripple marks, rain prints, sun cracks and some indeterminable markings like worm tracks. (see photo 22(j) 22(f). The sandstones and quartzites are strongly jointed and, where the dips are low, provide a distinctive tessellated pattern from the air. The two dominant joint planes are close to vertical and commonly trend northwest-southeast and northeast-southwest. Furthermore subhorizontal bedding in conjunction with close vertical jointing produces characteristically rugged outcrops.(photos 22(g) 22(b) 22(i).

This distinctive joint pattern and the structures within the Group constitute the principal evidence for correlating the beds of the Arnhem Land Plateau with the Buldiva Group (see photos 22(a), 22(b), 22(c). However outcrops of the Buldiva Group were inspected by G.A. Stewart at Connon Hill near the edge of the Arnhem Land Plateau to the north (Map reference 635/410) and these are described as hardened sandstones with some quartzites, grits and conglomerates (photo 11 (c)). Stewart also examined outcrops of the Group in the Katherine gorge (Map reference 587/187) and found quartzites and hard conglomerates, with well-worn boulders, lying sub-horizontally or dipping to the north-east at angles up to 25° (see photo 9 (e). Furthermore, the edge of the Arnhem Land Plateau was examined by the Aerial, Geological and Geophysical Survey of Northern Australia approximately 28 miles north of Katherine in 1939. The similarity of these rocks to those of the Buldiva Group was recognised and the outcrops were mapped as Cambrian on the plan produced in the Annual Report of the Survey for 1939.

The Buldiva Group, although sub-horizontal in most places, shows some steep dips, probably due to monoclinal folding, and sharp folds have been observed adjacent to major faults such as those bounding the Rock Candy Mountains in the Daly Valley (see photo 22 (e)). The beds exposed in the Arnhem Land Plateau commonly show dips which range from sub-horizontal to 30 degrees in a north-easterly direction. These are in marked contrast to the sharp buckles developed against major faults. One such fault is clearly shown in air photographs in the cliffs on the right bank of the Katherine River about 12 miles above the town. In this locality strata with a low north-easterly dip have been buckled against the fault and turned into a vertical position (see photo 22d). Identical structures adjacent to faults were observed in aerial photographs along the edge of the tableland to the north.

The maximum thickness of the Group is not known and the thickness observed varies considerably with the structure of the beds in relation to old surfaces of erosion. Sections which must aggregate several thousands of feet can be seen in the aerial photographs in places where the Group has been folded but no actual measurements have been made.

<u>b. Age of the Buldiva Group</u>. The Buldiva Group was previously considered as Upper Proterozoic or Lower Cambrian in Age (Voisey 1939a). The evidence now appears sufficient to place the group in the Upper Proterozoic and to postulate either an interval of erosion before the Cambrian sediments were laid down or a definite overlap of the Buldiva Group by the Cambrian beds.

In the past the Group was considered conformable with the overlying Cambrian limestones because both Groups showed comparable dips in the sections examined in the Buldiva area (Voisey, 1939a). No sections were found during the recent reconnaissance in which the relationship between the two Groups could be clearly seen. The road to the Daly River Police Station passes from Cambrian limestone onto the Buldiva Group (Map reference 386/275) but here the observer passes from gently dipping limestones on to gently dipping quartzite across a wide zone in which an actual contact was not found.

The real evidence of what may be termed a regional unconformity between the two Groups lies in the fact that the Cambrian limestones are found in many places to rest directly on Lower Proterozoic metamorphic or granitic rocks. If the two groups are conformable then the Cambrian limestones must have overlapped the Buldiva Group but this supposition appears untenable when the wide distribution of the Buldiva Group is taken into account.

A point of considerable interest is that the Buldiva Group appears very comparable to some of the strata mapped by Wade as Lower Cambrian in the Kimberley Division of Western Australia and in the northern portion of the Northern Territory (Wade, 1924). Wade describes quartzites, indurated shales and siliceous flags with some calcareous horizons from the Osmond Range in the Kimberley Division. These sediments underlie the volcanics which Mathieson and Teichert (1947) have identified as lying at the base of the Cambrian. Wade describes well preserved ripple marks in the quartzites as well as worm burrows and a variety of unidentified fossil markings.

Wade found quartzites with similar markings in the Victoria River and along the Arnhem Land coast of the Northern Territory and mapped them as Lower Cambrian. The conglomerates, quartzites, grits and shales which Wade describes as Lower Cambrian from Elcho Island, Cape Wilberforce and from other places along the Arnhem Land coast appear referable to the Buldiva Group which forms the eastern and southern edges of the Arnhem Land Plateau. Wade mapped this Plateau as "sandstone of unknown age" but he does not mention visiting the area and presumably based his conclusion on an older map by Woolnough (1912).

The work of Mathieson and Teichert (1947) in the Kimberley Division indicates that sediments lying below the volcanics must be older than Cambrian. The quartzites described by Wade from the Mount Osmond Range may, therefore, be regarded as Upper Proterozoic and, if his correlations are correct, the beds along the Arnhem Land Coast are of the same age. This in turn indicates that the Buldiva Group is Upper Proterozoic and probably correlable with the Nullagine series of Western Australia.

There is no evidence known to the writer from elsewhere in Australia which indicates an interval of erosion between Nullagine and Cambrian sedimentation, although some erosion of Nullagine sediments before the outpouring of basalt in the Kimberley Division could be inferred from a geological section (Section 1) shown in Wade's report of 1924. The apparent regional unconformity between Nullagine and Cambrian sediments north of the Daly River therefore warrants closer investigation. However, the volcanics of the Kimberley Division which occur between Nullagine sediments and Cambrian limestones represent a time interval between the two periods of sedimentation. No trace of these volcanics has been recorded to the south in the Macdonald Ranges, and they appear only sporadically north of the Daly River. If the volcanics are terrestrial they represent a definite break between Nullagine and Cambrian sedimentation in the northern portion of Australia and erosion of the Nullagine sediments might have taken place to the north of the Daly River where the protective covering of volcanic rocks was largely absent.

3. <u>Lower Cambrian</u> (?) - Volcanics.

<u>a. The Volcanic Rocks.</u> Volcanic rocks have previously been recorded from three localities within the region - on the Edith River by Maude Creek in the Katherine area, and at Collia Creek, south of the Daly River. None of these areas was examined

by the writer but two small additional outcrops were found. These three suites of volcanic rocks for which the names Edith Creek Volcanics, Maude Creek Volcanics and Collia Creek Volcanics are suggested have many features in common and, since there is no evidence to the contrary, they are considered to be contemperaneous.

Woolnough (1912) describes the Edith Creek volcanics as basaltic rocks, ranging from dacites to basalts, accompanied by tuff, agglomerate and tuffaceous sandstone. These are folded into small anticlines and synclines but the predominent dip is towards the east. Woolnough considered that these volcanics were underlying the Cambrian strata in the vicinity of Katherine but Jensen (1915) disagreed with this conclusion and thought that the volcanics were Permo-Carboniferous. The writer examined exposures along the main road north of Katherine and found Cambrian limestones overlying a ferruginous tuffaceous sandstone. In the aerial photographs this sandstone can be traced to the north into the volcanics with which it appears to be intercalated. Hence the writer believes that Woolnough offered the correct interpretation and that the Edith River volcanics underlie the Daly River Limestone Group. The air photographs indicate that on the west these volcanics are faulted into Lower Proterozoic metamorphics and on the east are faulted against the Upper Proterozoic Buldiva Group which also dips gently to the east. The topographical relief and the structure of the Buldiva Group in this area led Woolnough to consider them as younger rocks overlying the volcanics.

Less information is available concerning the Maude Creek volcanics but Woolnough (1912) states that volcanic rocks can be traced at intervals from Edith River to a point three miles south of Maude Creek where amygdaloidal basaltic rocks occur. Purple tuffaceous rocks dipping south-east at 45° are recorded by Woolnough (1912) along the Katherine River about 4 miles north of Katherine but these are considered to belong to the Brocks Creek Series.

The Collia Creek volcanics which outcrop in the headwaters of the Fish River near Buldiva are described as gritty felspathic quartzites passing upwards into tuff and overlain by porphyritic lavas (Voisey, 1939a). These volcanics rest on the Buldiva Group and are overlain by Mezozoic sediments of the Mullaman Group.

Two very small outcrops of volcanic rocks were mapped recently - an outcrop of basalt which forms a bar across the Daly River near the southern end of the Rock Candy Range (Map reference 375/236) (Photo 22(k)) and an outcrop of trachyte near the Daly River road (Map reference 383/278). Both these outcrops appear to rest on rocks of the Buldiva Group but their relationship to the Cambrian Limestone could not be determined.

<u>b. Age of the Volcanics.</u> The Age of these volcanic rocks has been a source of contention for many years and the field evidence is still not sufficient to establish their age beyond doubt. However, it is suggested that all of these volcanics are of Lower Cambrian age and that they overlie the Buldiva Group and underlie the Daly River Limestone Group.

The evidence for this may be summarised as follows -

In the first place all of the volcanics rest on Pre-Cambrian rocks of either the Brocks Creek Series or of the Buldiva Group and have not been found overlying Cambrian Limestone or any younger deposits.

In the second place the volcanic rocks appear to be genetically associated with the extensive volcanics found to the south and typically developed in the Kimberleys. Jensen recognised this and suggested a correlation in 1915 (Jensen, 1915). However, he placed the volcanics in the Permo-Carboniferous, partly from his own observations of the outcrops of volcanic rocks between the Upper Daly River and Tanami to the south, and partly from old reports, including one by Hardman (1903), in which the age of the volcanics in the Kimberley area was considered to be Devonian or Post Devonian. However, since 1915 it has been established that the volcanics in the Kimberleys underlie the Cambrian limestones and Mathieson and Teichert (1947) placed these volcanics in the Lower Cambrian - between the Cambrian limestone and the quartzites of the Mount Osmond Range which are regarded as Nullagine.

A perusal of Jenson's report in which he considered the volcanics as younger than the Cambrian limestone shows that the outcrops he described in 1915 from south of the Daly River were very similar to those found in the Kimberleys and he may have been mislead by the fact that the volcanics are, in places, topographically higher than the limestones which overlie them because of the basin structures developed by folding subsequent to the deposition of the limestone.

It seems therefore that the Lower Cambrian volcanics of the Kimberley region can be traced to the north almost to the Daly River itself, and hence, very substantial evidence will be required before the volcanics of the Katherine and Daly River areas can be reasonably considered as younger than the extensive volcanics to the south.

However, vulcanism was apparently much less extensive in this northern area and regional evidence suggests that similar conditions applied to the east and south-east, since Lower Cambrian volcanics are not represented at the base of the Cambrian sediments in north-western Queensland. The Edith River, Maude Creek and Collia Creek volcanics and the two small outcrops of volcanic rocks in the Daly River basin are therefore considered to represent isolated outbursts of vulcanism in Lower Cambrian time.

4. <u>Cambrian.</u>

<u>a. General</u> - The Cambrian sediments lie entirely within the Daly River watershed, in the southern part of the region. No details of the sequence have been established but the sediments appear divisible into two Groups, the Daly River Limestone Group and the Florine Group. These two divisions of the Cambrian were recognised in the field but there is not sufficient data to map the Florina Group with any accuracy. However, a very approximate boundary is indicated on the map for the benefit of the soils and pastoral work and this boundary will doubtless require considerable modification.

The Cambrian sediments in this region lie in a structural basin to which the name Daly River Basin may be applied. Course basal phases are apparently lacking which suggests that the sediments were deposited in a quiet transgressive sea.

<u>b. Daly River Limestone Group</u>. This lower group consists of limestones, sandstones, ferruginous sandstones and shale. The basal beds appear to be unfossiliferous but a Girvinella horizon has been found higher in the Group. These sediments dip at very low angles and have been gently folded. Outcrops are comparatively few so that no estimate of thickness can be made

without more detailed structural and stratigraphical work. Sediments near the base of the Group are well exposed in a section at the foot of a mesa on the Tipperary Road (Map reference 420/275). At this point about 150 feet of alternating flaggy silicified limestone and sandstones are exposed. The sandstones are soft and unaltered and are largely composed of the fine angular quartz grains which are characteristic of the sandstones of this Group. These beds rest on the Brocks Creek Series, although the actual contact was not observed. A close search failed to reveal any fossils, and the lower portion of the Group, here and in other areas such as Katherine, appear to be unfossiliferous. Further south, along the Tipperary Road, some 9 feet of marls are exposed on the bank of Station Creek (Map reference 410/260). These are higher in the sequence and may contain fossils although none was found on this occasion.

The only fossils found in the Group came from a limestone horizon outcropping 5 miles south-west of Tipperary Station where the rock was almost entirely composed of Girvinella (photo No.22e). A similar occurrence has been described by Voisey (1939a) from near the head of the Fish River south of the Daly and if this proves to be the same horizon it will be a useful key bed in the Daly River Limestone Group. It probably lies in the middle or upper portion of the Group and appears to be several hundred feet above the base.

The strike of these sediments varies but is generally northwest-southeast in the Tipperary area and, although gentle folds are apparent the general dip appears to be to the southwest at angles which range from 2 to 10 degrees.

Although individual horizons are not vey thick the limestones and sandstones of this Group provide good aquifers and the apparent basin structure suggests that artesian water may be obtained from the central portion of the Daly River Basin. The Buldiva Group underlies much of the Basin and the sandstones of this Group should also contain water.

c. <u>The Florina Group</u> - This Group forms the upper part of the Cambrian sediments and consists very largely of sandstones. Some thin beds of limestone may be present but fairly soft sandstone appears to be the predominant rock type. In areas occupied by the Florina Group the soils are sandy and appear not to be calcareous. These sandy soils can be traced westward into the centre of the Daly Basin between the Douglas and Daly Rivers. In this locality the ferruginous sandstones and shales on Gypsy Creek (Map reference 441/238) may lie near the base of the Florina Group (see photos 22(m) 22(n)).

Sandstones of the Florina Group form flat-topped hills in the vicinity of the Daly River, below its confluence with the Flora, and these hills are remnants of an old land surface on which Mesozoic sediments were eventually deposited. For this reason they were classed with the "Tableland Sandstones" and mapped as Permo-Carboniferous by Jenson in 1915.

d. <u>Comparison with Cambrian Sediments in Western Australia and Queensland</u> - The Cambrian sequence in the Kimberley Division of Western Australia has been worked out in some detail by Matheson and Teichert (1947). They divide the Cambrian sediments into two conformable Series - the Negri Series overlain by the Mount Elder Series. The Negri Series consists of limestones and shales, some of which are fossiliferous, and the Mount Elder Series is compsed largely of sandstones. Teichert has reviewed the palaeontological evidence for the age of these Cambrian sediments and places the Negri Series in the Lower Cambrian.

The sediments of the Daly River Limestone Group appear comparable with the Negri Series and are, therefore, regarded as Lower Cambrian and the Florina Group appears equivalent to the Mount Elder Series.

The oldest Cambrian sediments known in North-western Queensland occur at the base of the Templeton Series (named after the Templeton River) and consist of sandstones, siltstones, cherts, and non-calcareous sediments (Bryan & Jones, 1945). The oldest of these sediments are referred to the uppermost part of the Lower Cambrian. The Templeton Series is developed to the west on the Barkly Tablelands, but it is here represented by a limestone facies. It is therefore likely that the Daly River Limestone Group can be correlated with at least a part of the Templeton Series of Queensland.

5. Upper Palaeozoic.

a. Permian - Port Keats Group - Sediments of the Port Keats Group outcrop in a belt along the western seaboard of the region south of Port Blaze. In the latitude of Mount Greenwood the belt extends inland for about 40 miles and to the south the belt appears to be even wider. In some places these sediments are masked by recent alluvium and by mesas formed in Mesozoic sediments but they outcrop consistently in the headlands south of the mouth of the Daly River.

Permian fossils were first found by Commander Stokes near the mouth of the Victoria River in 1886 and the outcrops here and at Port Keats were subsequently described by Browne in 1905. Browne states thatthe rocks at Fossil Head consist of sandstone, shale and sandrock and provide the most typical section of the beds. These lie almost horizontally but show a tendency to dip westward. Bores were subsequently put down at Port Keats to test for coal seams and these established the following sequence of beds (Browne, 1906).

	Surface Feet
Micaceous sandstones and shales with a little coal between 360 and 362 feet from the top	420
Micaceous argillaceous shale slightly carbonaceous in part and containing Estheria	43
Green and blue fossiliferous arenaceous shale with blue argillaceous sandstones	112
Fossiliferous polyzoan limestones	9
Sandstone	30
Pyrites and fossiliferous limestone	16
Blue sandstone, etc.	94
Black carbonaceous shale with Glossopteris and Noeggerathiopsis.	6
	730

During the recent reconnaissance an attempt was made to reach the coast at Redcliff, which lies south of the Daly River, but the coastal plains proved too wet and the party was obliged to turn back when 8 miles from the coastline. The Port Keats Group in this area occupies low-lying, very gently undulating country (photo 8(a)). Very few outcrops could be found but the composition of the soils indicated that sandstone was the predominant rock type. The only good exposure of the group was found at the base of Mount Greenwood under a capping of Mesozoic strata. The section showed approximately 130 feet of sandstone with intercalations of sandy shale but a careful search failed to reveal any identifiable fossils. Most of the sandstones and particularly those exposed at the base of the section were noticeably friable and appear comparable with the "friable sugary sand-rock" which Bowne (1905) describes from Fossil Head. The beds at Mount Greenwood were striking north-west and dipping south-west at low angles which averaged approximately 5°.

On the geological plan, an outcrop of the Port Keats Group is shown between Anson and Fog Bays, north of the Daly River. One traverse was made across this area but most of the outcrops consist of laterite and the geology is based on soil interpretation. The underlying rocks are apparently shales, sandy shales and sandstones. Argillaceous rock appears predominant and some of the shales are calcareous particularly in the western part of the area. Fragments of shale and sandstone were found under a laterite in one locality near the western edge of the area but thse gave no clue to structue and contained no palaeontological evidence beyond occasional worm tracks. The age of the sediments in this area is, therefore, in doubt but they have been provisionally mapped as Permian because of their lithology and geographical position.

b. Elliott Creek Formation. - Sediments of the Elliott Creek Formation occupy a gently undulating terrain to the north of Mount Litchfield. The formation includes a succession of apparently thin beds of sandstone, shale and limestone which lie horizontally in most of the outcrops examined. Outcrops are infrequent and geological information was based on auger hole samples over the greater part of the traverse made across the formation.

The basal beds are hardened sandstone overlain by brown somewhat flaggy rocks which are very similar in appearance and grain-size to sandstones of the Daly River Limestone Group. Shales, sandstones and limestones appear higher in the sequence and these appear to alternate and provide many changes in soil across the gently undulating terrain. Only one bed of flaggy limestone was found in outcrop and this appeared to be 2 to 3 feet thick (see photo 22(p)). The bed lay horizontally but had been extensively weathered and did not form continuous outcrops. Some outcrops showed markings which strongly resembled the remains of coral. Miss Crespin, Commonwealth Palaeontologist, has examined specimens from this outcrop but has found no conclusive evidence of the age of the limestone although it is considered to be Upper Palaeozoic and possibly Devonian. The thickness of the Elliott Creek Formation cannot be estimated but most of the outcrops appear to be approximately horizontal and if this is so a thickness of less than 500 feet is indicated.

The stratigraphy of the western portion of the region suggests that the Elliott Creek Formation is Permian but additional field and palaeontological work will be required to establish the relationship of the Elliott Creek formation to the Port Keats Group.

6. Mesozoic.

Mullaman Group - Sediments of the Mullaman Group outcrop in a narrow belt along the north-west coastline in the Darwin area and in flat-topped hills in the higher country to the south and south-east (see photos 10 (a) 10 (b)). The Group may be divided into at least two portions - an upper portion consisting mainly of shale and sandy shale bearing Lower Cretaceous fossils to which the name Darwin formation has been given and a lower portion which consists of sandstones and basal conglomerates. No formal name is proposed for these lower beds since their relationship to the overlying shales has not been adequately defined and consequently the sediments of the Mullaman Group have been mapped as one unit.

The lower beds of the Group appear to be freshwater lacustrine deposits of Late Jurassic or Early Cretaceous age and may represent passage beds in that they appear to pass upwards into marine Lower Cretaceous shales. Voisey (1939a) found plant fossils near the base of the Mullaman Group in the Buldiva Area. These were in situ and included Otazamites bengalinsis which has been found only in strata of Jurassic age in Australia, although fairly abundant in both Triassic and Lower Cretaceous formations in other places. No plant fossils were found in other localities during the limited time which could be devoted to the search for them. However, there is evidence that sandstone and conglomerates occur at the base of the Mullaman Group over a very wide area, in the central, southern and south-eastern parts of the region and this suggests that fresh water lakes developed in these areas towards the close of Jurassic or at the beginning of Cretaceous time. A section described by Jensen (1914) at Boorooloola includes an uppermost formation containing fossilised wood which may well represent the Lower bed of the Mullaman Group and Whitehouse (1945) records a fragment of quartzites bearing Otazamites from the Barkly Tablelands. There is little evidence of these lower beds under the Cretaceous sediments in the Darwin area and it is doubtful if they are represented at Mount Greenwood to the south and this suggests that a westerly or north-westerly limit of the lacustrine sediments lies between Adelaide River and Darwin.

Lower Cretaceous sediments were first described from the Darwin area by Brown (1906) and the palaeontology was described by Etheride (1906). The beds originally consisted of fine shales and sandy shales resting unconformably on the folded Brocks Creek Series. In some places beds of grit or fine conglomerate occur at the base of the formation. The greatest thickness observed in the Darwin area amounts to about 40 feet and the total thickness of the formation in this area is probably little more than 50 feet.

The original shaly sediments have been extensively lateritised and the upper layers converted into a tough fine-grained rock to which the name porcellanite has been applied (Voisey 1939a) ("Magnesite" of Tenison Woods.) The rock is usually white, yellow brown or mottled dependent on the distribution of limonite-staining. The thickness varies and up to 30 feet of this material is exposed in sections in the vicinity of Darwin (photo 10(c)). This porcellanite is considered to be of pedological origin and represents the B_2 or lower pedological horizon formed during lateritisation of a Tertiary land surface. Movement of silican and iron took place during this process and the shales were leached of iron but cemented by redeposited silica. The soil cover and the upper soil horizon of massive laterite were eventually removed by erosion and the porcellanite exposed as a form of duricrust. The porcellanite is therefore not a stratigraphical horizon although it behaves as one in most places because the strata are predominently flat. The extent to which the porcellanite is transgressive will not be known until details of the Lower Cretaceous sequence are worked out. The source of the readily soluble silica is not known but there seems to be a close connection between radiolarian shale and porcellanite and it appears likely that the radiolaria have themselves provided the silica. The porcellanite is very widespread and radiolaria have been found in specimens of the rock in widely different localities. It seems significant that the only outcrops of Lower Cretaceous rocks upon which a cap rock of porcellanite was not found were those in the vicinity of Fog Bay where the sediments were more arenaceous than those in the vicinity of Darwin and where radiolarian shales have not been identified (photo 16(a).

G.A. Stewart believes that the texture of the parent material was an important factor in the formation of porcellanite and he suggests that it was formed in shales which were intermediate in texture between the coarse sandy phases and the fine clay material. The pedological processes involved in the formation of porcellanite are discussed by G.A. Stewart in his report on soils.

The Darwin formation is found occupying flat-topped hills south and east of Darwin (photos 10(a), 10(b)). These mesas owe their characteristic sharp profile to the porcellanite which forms a tough cap rock over the underlying shales and sandstones. There is little doubt that porcellanite was formed only in shales of the Darwin formation and Lower Cretaceous radiolaria have been identified by Miss Crespin in porcellanite from Darwin, Buldiva and from mesas between Pine Creek and Adelaide River. A cast of Dimitabelis has been identified by Miss Crespin in a specimen of cap rock from Mount Greenwood. Marine fossils of probable Lower Cretaceous age have also been found at Yeuralba north-east of Katherine.

The thickness of the outliers of the Mullaman Group mapped from air photographs on the Arnhem Tableland is probably less than 100 feet. The cap rock has been eroded off in some places but is present in others and hence the Darwin formation is almost certainly represented (see photo 22 (a)). The characteristic outcrop of the cap rock became the principal criterion of rocks of the Mullaman Group in extending the mapping by air photographs and outcrops of this Group have probably been missed in areas where the cap rock has been eroded away.

The maximum observed thickness of the Mullaman Group was approximately 210 feet in a mesa south-east of Brocks Creek (Map reference 464/267).

In this section the Group consists of sandy sediments with at least one conglomerate bed toward the base. The uper 20 feet consists of white or buff coloured porcellanite overlying two feet of conglomerate. The porcellanite shows a tendency to develop vertical cracks like columnar jointing but traces of bedding could be seen in the material and this lay approximately horizontal. The lower portion of the section was covered by detrital material and the detailed sequence could not be established.

At Mount Greenwood the upper 90-100 feet of sediments probably belong to the Mullaman Group and consist of 70 to 80 feet of shales and sandy beds overlain by 16 feet of porcellanitic material which includes an interpolation of ferruginous sandstone. The sandstone bed is horizontal and shows little alteration by pedological processes.

7. Tertiary and Quaternary Laterites.

Areas of laterite have been delineated on the geological plan wherever possible on account of their importance in soil interpretation but the underlying parent rock is indicated in all laterite areas. The extensive areas of laterite all lie in the northern and north-western parts of the region because in these areas the landscape is more mature and the rate of erosion comparatively slow. Laterites and partly formed laterites are found in many localities and at various levels in other parts of the region but are not sufficiently extensive to appear on the plan.

The laterites have been fully described by G.A. Stewart in his report on soils but the two main divisions may be mentioned here. The laterites capping the Darwin formation along the north-west coast are considered to be Tertiary laterites. They were formed during Tertiary time on a low-lying land surface which was eventually uplifted and partly eroded in Pliocene time. They are contemporaneous with the porcellanite and belong to the same soil profile (photo 13 (c)). Further inland, on the mesas, these laterites have been removed, for the most part, but remnants of them in the form of pisolitic ironstone gravel can be found overlying porcellanite.

The laterites shown overlying granite and Lower Proterozoic rocks are post-uplift laterites which formed in Pleistocene and Recent time. These occur at various levels and formed wherever geology and topography were suitable over sufficient intervals of time. These laterites masked all outcrops in most places but the character of the underlying rock could be deduced from an examination of lateritised material obtained from auger holes.

8. Pleistocene and Recent Deposits.

Pleistocene and Recent deposits consist mainly of river and coastal plain alluvials which occupy large areas of the northern and western plains. The marine coastal plains are the more extensive of the two and extend inland for many miles along the valleys of the principal streams (photos 11(a) 11(b)). They consist of mud and fine sand deposited in drowned river valleys. These resulted from the last significant submergence of the coastline which Browne (1945) places toward the close of Pleistocene time. Well preserved crayfish are found in these estuarine deposits at several places around the coast.

The rise in base level consequent on this submergence caused extensive alluviation along the river channels inland from the estuaries and some of these stream alluvials on the northern plains are sufficiently extensive to appear on the geological map (photos 2(a), 2(b). These alluvials consist largely of fine sand and silt with some gravels at the base of the deposits. The thickness and size of the gravel underlying the alluvium probably increases upstream toward the head waters where erosion is still active.

In Mid-Recent time the final eustatic movement took place and sea level fell about 20 feet to expose the estuarine deposits and slightly rejuvenate the lower courses of the streams. The exposed estuarine deposits became the coastal marine plains and these carry raised beaches and shell remains for some miles inland from the present coast line.

Eustatic movements in Pleistocene and Recent time produced a series of coastline oscillations (Browne,1945) and the deposition and subsequent exposure of the marine coastal plains have been referred to the latest of these movements - a submergence which Browne places at the end of the Pleistocene followed by an emergence in Middle Recent time. More detailed mapping in the region may provide evidence of some of the earlier Pleistocene oscillations which cannot be satisfactorily traced at present.

Some small lakes were formed by valley constriction during the present cycle of erosion. Conglomerates and sandy sediments were deposited in these and eventually removed or partly removed by stream erosion. Remnants of Recent conglomerate were noted at the head of the Margaret River, 5 miles south of Grove Hill and similar lacustrine beds were observed in the banks of a small stream between the Douglas and Daly Rivers (Map Reference 445/242).

V. STRUCTURAL GEOLOGY.

A. FOLDING.

The only close folding found in the region was noted in beds of the Brocks Creek Series and some details of these structures have been published in reports of the Aerial, Geological and Geophysical Survey of Northern Australia.

Both the Buldiva Group and Daly River Limestone Group show some degree of folding but there is not sufficient data to determine whether both these Groups were folded together after the Cambrian sediments were deposited or whether some structures in the Buldiva Group are referable to Pre-Cambrian movements. Certainly both Groups have been subjected to similar broad folding movements although the pronounced jointing and monoclinal folding observed in the Buldiva Group appear to represent stronger forces than those responsible for the jointing and folding of the Cambrian beds.

The structure and distribution of the Buldiva Group suggests a pattern of very broad domes and basins. Basin structures are apparent in the Daly River area where dips are to the east or south and on the Arnhem Land Plateau where the beds dip consistently to the north-east. The sediments were apparently arched between these areas and remnants of the domal structure are preserved near Hayes Creek and south of Adelaide River. The distribution of Upper Proterozoic and Cambrian sediments in the vicinity of Hayes Creek suggests that folding and some erosion of the Buldiva Group may have taken place before Cambrian sedimentation but further field work will be required before the sequence of events can be established.

B. FAULTING.

Prominent faults encountered in the field or identified in aerial photographs are shown on the geological plan. Some of these can be referred to the Late Tertiary uplift and other unmineralised faults which traverse the Brocks Creek Series or the Buldiva Group are probably not younger than early Paleozoic. On the Arnhem Land Plateau the faults against which the Buldiva Group is buckled, probably belong to this older Group.

The most prominent faults in the area were associated with the Late Tertiary uplift and are marked by strong topographical expression and, in places, by hot springs. The most prominent of these bounds the western edge of the Mount Tolmer Plateau and trends a little west of north for at least 50 miles.

Upper Palaeozoic beds of the Elliott Creek formation and overlying Mesozoic sediments are down faulted against the Pre-Cambrain rocks exposed on the Tolmer Tableland. The attitude of the Mesozoic beds on either side of the fault suggests a throw of at least 100 feet. Another prominent normal fault trends in a north-westerly direction normal to the Douglas River some 30 miles above its confluence with the Daly. Here Cambrian Limestones on the south-west have been faulted down against metamorphics of the Brocks Creek Series.

Hot springs occur in many places, particularly in the Daly River basin and all those encountered were associated with limestone and, probably, with faults.

VI. GEOLOGICAL HISTORY.

Archeozoic rocks have not been identified in the northern portion of the Territory and the geological history of the area opens with the deposition of the Brock's Creek Series in Lower Proterozoic time. This thick series of marine sediments was deposited in a great geosyncline which probably extended to the south and west into north-western Australia where the Mosquito Creek Series appears of comparable age.

The Brock's Creek Series was subsequently folded and intruded by granite. Folding and intrusion of Brock's Creek Series provided the only evidence of major diastrophism in the region which has maintained a remarkable degree of stability since Lower Proterozoic time.

Uplift and a considerable period of erosion ensued until the area was again submerged and the sandstones of the Buldiva Group deposited. The Buldiva Group was probably many thousands of feet in thickness and consisted mainly of sandy sediments deposited in the Upper Proterozoic Sea beneath which vast areas of the Australian continent were submerged. The Buldiva Group rests with a marked unconformity on the Lower Proterozoic rocks which appear to have been reduced to a peneplain before the Upper Proterozoic marine transgression.

The deposition of the Buldiva Group was followed by isolated outbursts of vulcanism in early Cambrian time and this in turn by the deposition of limestones and sandstones in a quiet transgressive Lower Cambrian Sea. The relationships between these transgressions is obscure, but there is a suggestion that a period of uplift and erosion may have intervened between the deposition of the Buldiva Group and that of the Lower Cambrian sediments.

The uplift which followed Cambrian sedimentation was accompanied by little deformation and consequently the Lower Cambrian sediments show little alteration and very gentle folding.

In the Northern Territory this uplift ushered in a period of remarkable stability which has extended, with only minor interruptions, from Cambrian to Recent Time. As a result of this stability, the area has remained one of comparatively low relief over the greater part of this period. The fact that the Cambrian sediments were not entirely removed during the long Palaeozoic era, despite the apparent lack of a protective covering, implies that the relief of the area was never high for any considerable period of time. The Lower Cretaceous land surface represented by the surface on which the sediments of the Mullaman Group now rest included large areas of comparatively soft Lower Cambrian sediments in the Daly Basin which were not to be extensively eroded until late in the Tertiary era.

However, active sedimentation took place during the Palaeozoic in the East Indies geosyncline to the immediate west of this region and the fringe of Upper Palaeozoic sediments along the western coast suggests that, during much of Palaeozoic time, the northern portion of the Territory remained a low-lying stable block which formed the eastern margin of the East Indies trough.

The Upper Palaeozoic sea probably reached its greatest eastern extension during Permian time when sediments of the Port Keats Group were deposited. The margin of the geosyncline moved westward after the deposition of the Permian sediments and by the end of the Jurassic the region was apparently a peneplain cut in Pre-Cambrian, Lower Cambrian and, to the west, in Permian rocks.

Cliff sections along the north-western coast provide some interesting evidence of the nature of this Mesozoic land surface. Remnants of laterite were found at the base of the Darwin formation at Point Charles (photo 13(a) and although these could belong to the Tertiary laterite profile, they appear to be older than the Darwin formation. The laterites rested on leached and kaolinised Pre-Cambrian metamorphics which are characteristically found beneath the Darwin formation along the north-west coast. These remnants may indicate that the climate prior to the marine transgression in the Lower Cretaceous must have been conducive to lateritisation with high rainfall.

The sandy beds at the base of the Mullaman Group suggest that fresh water lakes developed in the central eastern and southern parts of the area at the end of the Jurassic or at the beginning of the Cretaceous, but the north-western portion of the region was not effected until a epieric sea submerged the entire area in Lower Cretaceous time. Fine-grained sediments including radiolarian shales were deposited in this sea which can be traced eastward of Katherine and may have been continuous with the great Lower Cretaceous sea which covered much of Queensland.

The Mullaman Group includes the latest marine sediments of any consequence in the northern portion of the Territory. The Mullaman Group was probably never very thick and the maximum thickness of the present exposures beneath the Tertiary land surface is little more than 200 feet. The fact that this Tertiary peneplain in the northern part of the Territory was cut solely in sediments of the Mullaman Group clearly suggests that the uplift in Mesozoic time must have been slight and comparatively even.

Thus the cycle of erosion which was initiated in Cretaceous time and continued without interruption until the late middle Tertiary began with a fairly flat low-lying land surface which presented little scope for erosion. Under conditions of high rainfall and with a substratum of soft sandy shales conditions for lateritisation were ideal and a very deep laterite profile was developed. The so-called "porcellanite" of the Darwin formation was formed as a soil horizon below this Tertiary land surface. The toughness of this material played an important part in the ensuing cycle of erosion and little would remain of the Mullaman Group if it were not for the protection afforded by this fossil soil horizon.

The final movements which initiated the present cycle of erosion cannot be accurately placed but probably occurred in Late Miocene or Pliocene time and were probably synchronous with late Tertiary folding in New Guinea and with Late Tertiary uplifts in other parts of Australia. The present position of the porcellanite representing the older land surface provides a useful clue to the nature of the late Tertiary uplift. The movement probably took place gradually over a considerable period of time and the principal structure was a broad warp, made somewhat irregular by normal faulting, by which the old surface was warped upwards to the south-south-east. (See Geological Sections). The maximum elevation appears to have been attained in the vicinity of Pine Creek, as the porcellanite cap rock is lower to the south, across the Daly, and to the south-east near Katherine.

VII. GEOMORPHOLOGY.

At the commencement of the present cycle of erosion the region had a low but definite relief and it is possible to trace the development of the three main topographical divisions- the northern plains, the western plains and the Daly River Basin.

All the stream erosion below the level of the porcellanite has occurred since late Tertiary time and some idea of the amount of erosion can be obtained from the sections accompanying the geological plan.

A. NORTHERN PLAINS.

The development of the northern plains is the easiest to trace. Consequent streams developed down the slopes of the warped Tertiary surface. They probably run in a north-north-westerly direction at first and slowly cut through the porcellanite and entered the Lower Proterozoic rocks below. The dominant north-south structure of the Brocks Creek Series then determined the drainage pattern and produced a northerly flowing river system. This structural control is still evident in the upper portions of the rivers which flow north-west from the main divide. With the advancing cycle the outcrops of the Mullaman Group became an incised tableland and eventually this was converted into isolate "doabs" by headward erosion of the streams. In Pleistocene time the northern plains reached an advanced stage of maturity with a wide distribution of laterite particularly in the northern portion where active erosion had almost ceased. Laterites had also formed in areas to the south wherever the local topography and geology were suitable.

The principal features which allowed maturity to be reached so quickly were - the northerly slope of the terrain before erosion commenced; high monsoonal rainfall; the deep leaching of much of the old erosion surface underlying the Mesozoic rocks and the fact that the rivers could follow the northerly structural trend of the Brocks Creek Series with few barriers to hold up erosion. The sandstone and quartzites of the Buldiva Group had apparently been removed from this area before Cretaceous time with the exception of one or two infaulted blocks which now form outliers towards the western edge of the plains.

The final stages of development of the northern plains were brought about by eustatic movements which affected all the Australian Continent in Pleistocene and Recent time. A considerable rise in sea level submerged the fringe of the mature northern plain and drowned the valleys of the principal rivers. Sand and mud were deposited in these broad shallow estuaries and the rise in base level caused alluviation of stream channels for many miles to the south. Sea level then fell about 20 feet during Recent time and this exposed the wide silted estuaries which now form the coastal marine black soil plains. The streams were slightly rejuvenated and carved new channels through their alluvial deposits and through the new esturine plains to the sea. Raised shallow beaches, sand dunes and marine benches are found everywhere along the Northern Territory coastline and provide abundant evidence of this latest marine recession.

B. WESTERN PLAINS.

The development of the western plains followed much the same pattern. Maturity was reached quickly in this area because of the down faulting of the western block; the original slope of the terrain and the softness of so much of tho rock beneath the Mullaman Group. In addition, considerable areas of the Tertiary peneplain may not have contained a fully developed porcellanitic substratum.

The rise in sea level in Pleistocene time flooded a great area of these plains causing alluviation further inland and the dumping of great quantities of sand along the foot of the Tolmer faultscarp. The subsequent fall in sea level created great areas of black soil plain and swamp and rivers such as the Reynolds have not had sufficient fall to cut channels through to the sea.

C. THE DALY RIVER BASIN.

South of the main divide, consequent streams penetrated the Mullaman Group into the Lower Cambrian sediments. These rocks in themselves did not offer great resistance to erosion but their sub-horizontal attitude prevented the streams from maintaining their channels in the most favourable strata as they could in areas of folded Lower Proterozoic rocks. Thus, erosion within the Daly River Basin has been held up in many places by horizontal bars which have imposed temporary base levels on the streams eroding them. Several low bars formed by tough limestone and in one place by basalt are still evident in the channel of the Daly River itself. Perhaps the principal reason why the Daly River Basin has not been more extensively eroded is that a barrier of tough Pre-Cambrian rocks lies normal to the course of the iver for many miles downstream from the Rock Candy Range. Both the quartzites of the Buldiva Group and the metamorphics of the Brocks Creek Series strike approximately north and south and they presented a formidable barrier. The Daly River swin s sharply to the north and north-west against the quartzites of the Buldiva Group and has been forced to follow structure in the series of gorges cut through to the western plains.

The Daly River Basin is still being actively eroded and has not reached the same degree of maturity as found to the west and north.

VIII. ECONOMIC GEOLOGY.

A. INTRODUCTION.

In this section of the report the present position of the mining industry in the region is summarised and some comments made on the future prospects of mineral development. Some notes on underground water and on petroleum prospects are included and suggestions for assisting the mining industry and for future geological work are submitted.

It was not possible to carry out detailed examinations of individual mines or of mining fields during the reconnaissance, but an attempt was made to visit all of the mines at present operated in the region, and brief inspections were made of mining activities in the Pine Creek-Adelaide River area (Agicondi and Woggaman Goldfields), at Batchelor, at the Finniss River (Woggaman Goldfield) and at Fletcher's Gully in the Daly River Goldfield. It was intended to visit mining centres at Wolfram Hill and Maranboy, but these visits had to be abandoned on account of sickness.

Mining leases at present held in the northern portion of the Territory are shown in Table 2. These are grouped under Goldfields, and mining areas are discussed under the same headings. A table showing the mineral production from the northern portion of the Territory from 1869 to 1946, has been included as an appendix to the report, but production figures from the individual mining areas are not available.

The information provided in geological and mining reports and particularly in those of the Aerial, Geological and Geophysical Survey of Northern Australia has been used in compiling the following summary and a list of these reports appears in the bibliography.

B. <u>THE MINING INDUSTRY</u>.

(1) <u>General</u> - Metalliferous deposits of commercial significance have been found only in Lower Proterozoic rocks of the Brocks Creek Series and are genetically associated with granitic intrusives. The metals introduced include gold, copper, silver-lead, tin, molybdenum, tantalum and tungsten. Oxidised ores have presented no treatment problems but many of the sulphide ores are complex and difficult to treat.

A broad zoning of the metals in relation to the major granitic intrusives is apparent in the regional distribution of the deposits. The widest distribution of the high temperature minerals tantalite and cassiterite occurs along the eastern margin of the Litchfield granite in metamorphics which show a higher grade of regional and thermal metamorphism than found elsewhere in the northern portion of the Territory. Deposits of copper, silver-lead and gold are found at greater distances from this contact in the Daly River Goldfield.

The same broad zonal arrangement is found associated with granite contacts in the more easterly mineral fields. Deposits of tin, molybdenum and tungsten are found close to granite, as at Mount Shoobridge, Mount Wells, Wolfram Hill, etc., and silver-lead and gold deposits are found at greater distances from the contact between the granite and the metamorphic rocks.

The metalliferous deposits occupy fracture systems in the Brocks Creek metamorphics or, in rare cases, occur as replacement bodies. In general all of these deposits are comparatively small.

The total value of mineral production from this region from 1869 to 1946 is £3,261,984, of which approximately two-thirds has been derived from gold. The value of annual production attained a maximum of £107,778 in 1891 but declined to approximately £43,000 in 1919/20 and has since fallen to £1,346 in 1946. No gold production has been recorded since 1938/40 but production of tin and wolfram continued throughout the Second World War. Wolfram was produced in 1943, 1944 and 1945 and small parcels of tantalite in 1943 and 1944.

The total value of tin and wolfram produced since 1938/40 is £32,665 but the value of production in 1946 was only £1,346.

(2) The Agicondi Goldfield - The Agicondi Goldfield includes mining centres in the neighbourhood of Pine Creek and extends approximately from Burrundie eastward to Mount Todd. Mining commenced in the 1870s. on this field and the maximum production was attained before 1900. Mining activity became intermittent during the present century and virtually ceased in 1935.

Deposits of gold, tin, wolfram, silver-lead and copper have been found mainly in zones marginal to the granitic intrusives, and alluvial tin has been worked within the areas occupied by the granite. Most of the past production, particularly in the earlier days of the field, has come from rich ore shoots in the oxidised zone. Very little mining has been done below water level and very few individual mine records have been kept. Thousands of Chinese, were employed in the early days of mining and many of these eventually worked alluvial and lode deposits as tributers, but their mining practices lacked method and co-ordination.

In consequence, most of the easily accessible payable ore has been removed from the many old mines and workings in the Agicondi Goldfield and, for most of these mines, there appear to be no adequate records of the grade and tonnage of ore which was extracted or which was exposed in developmental workings.

The only mines which are still held on the Agicondi Goldfield are the Hercules, the Eleanor and the Enterprise. These gold mines may warrant further investigation or development but as none of them has a treatment plant or adequate proved reserves of ore, there is no assurance that production can be resumed. It is probable that patches of alluvial will be sluiced for gold or tin during wet seasons but production from alluvial mining in the immediate future is likely to be small.

(3) Woggaman Goldfield - The Woggaman Goldfield includes a number of mining localities between Burrundie and the Western Coast. These include the Burrundie-Adelaide River district, the Batchelor district and the Finniss River district.

(a) Burrundie-Adelaide River District: This area includes some of the oldest mining localities and the general remarks made in regard to mining and future possibilities on the Agicondi Goldfield applies equally well to this district. Gold, tin and copper deposits have been mined in the past, but present production is limited to gold and tin and is very small. Ten gold mining leases are held in the district and one mineral lease is held at Mount Shoobridge.

The only producing centre at present is a syndicate mine near Grove Hill where a quartz stringer only 1 inch in width is sufficiently rich in gold to repay mining. The Fountain Head mine has the only battery in the area and this mine should be producing in the near future. However, it is small and only partly developed and is not likely to become a major producer. Production of gold is expected from alluvial deposits in the Shackle Creek locality and some tin should be produced from Mount Shoobridge.

Although there are no major mines from which production can be confidently anticipated there are several gold mines which may warrant further investigation, particularly the Golden Dyke, the Iron Blow and the Cosmopolitan Howley.

The extensive alluvial flats along the Mary, McKinley and Margaret Rivers have received some attention as potential dredging areas. Some of these flats on the Upper McKinley were inspected during the recent reconnaissance and it is considered unlikely that the gravels underlying these alluvials have been sufficiently enriched to warrant dredging. Flats on the McKinley have been drilled recently by a syndicate or company but no reliable information on the results of this testing has been obtained.

(b) Batchelor District: A gold-bearing quartz-tourmaline vein was discovered in the Batchelor area in 1943 and many leases were subsequently pegged in 1946. Fifteen leases are still held in the area but geological examination and further prospecting has shown that the area is unlikely to contain significant mineral deposits. Small high temperature vein deposits, similar to the original discovery, may occur in the locality but it is not one in which further prospecting can be recommended.

(c) Finniss River District: The Finniss River district lies in the meridional zone of pegmatite and greisen dykes which occur along the eastern margin of the Mount Litchfield granite. Many of these dykes contain deposits of tin and tantalite. Tin has been produced from this area at intervals from about 1882 but tantalite was not produced until 1906.

The district is divided into a northern and southern portion by the Finniss River. The Northern area between the Finniss River and Bynoe Harbour has been the more extensively worked in the past. The terrain consists of well defined meridional redges interspersed with wide flats which comprise at least one-third of the total area. Outcrops are only found along the ridges and in consequence the area has been well prospected in the past. It is probable that few new outcrops of pegmatite will be found in this area but investigation of abandoned workings is worthwhile. This applies particularly to eluvial material which consists of soil and detritus covering the slopes below the outcrops of pegmatite dykes and which, in many places, contain significant quantities of tin or tantalite. Some eluvial deposits have been worked in the past but only by the most primitive methods and the application of ground sluicing by nozzle and pump should be profitable at some of these deposits.

The lode deposits are typical of those found in pegmatite dykes in that values are patchy and mineralisation erratic. For this reason these deposits are not likely to justify exploration on a large scale but some may be suitable for syndicates or small parties who could extract the patches of payable ore.

There are no batteries or sluicing plants operating in the northern area at present but twelve mineral leases are held. Some prospecting is being carried out and a small company hopes to sluice the tin and tantalite-bearing eluvial material at Mount Finniss.

The southern portion of the area has good prospects and has not been intensively prospected. The Bamboo Creek tin mine at Bamboo Creek is producing tin from a pegmatite dyke and at least two other parties at Bamboo Creek and at Walkers Creek were prepared to ground sluice eluvial tin before the recent wet season. Removal of the eluvial cover will allow prospecting in the bedrock for lode deposits.

At the Bamboo Creek mine, tin ore, extracted by following erratic shoots within a pegmatite dyke or pipe, is treated in a small battery. The area may well contain other lode deposits such as this and future development may prove a sufficient number of small deposits to warrant the erection of a central treatment plant.

Some of the long narrow flats in this area should contain old creek channels under the alluvium. Such channels may contain tin-bearing gravels, and it is suggested that a selected flat be drilled to test for tin-bearing gravel.

The major problems in the Finniss River district at present are transport and communication during the wet season when the mining camps are completely isolated by flood waters for several months. Families cannot be established in the area with any degree of safety while these conditions pertain and it will be necessary to improve them if it is desired to establish a mining community in the area. Consideration might be given to methods of development of an aerial service and a teleradio installation which would provide essential transport and communication throughout the year.

4. The Daly River Goldfield.

The Daly River Goldfield lies in a narrow meridional belt of Lower Proterozoic rocks which extend north and south of the Daly River, from Buldiva in the south to the Reynolds River in the north. Gold, copper and tin have been produced from the field and deposits of silver-lead are known to occur. Much of this goldfield is very isolated and the only ground at present held is one gold mining lease at Fletcher's Gully.

There appears little chance of mining being re-established in that portion of the field that lies north of the Daly River. One prospector hopes to recover alluvial tantalite in the vicinity of Noltenius Billabong but the prospects of any significant production appear slight.

Tin and gold have been produced from Fletcher's Gully and from the Buldiva-Collia area, in the southern portion of the field. One gold mine is at present being worked at Fletcher's Gully but only a small production from narrow veins of higher grade ore is likely to result.

Both alluvial and lode tin have been produced from the Buldiva and Muldiva areas and a little alluvial tin has been produced from Collia. Reports of the Aerial, Geological and Geophysical Survey of Northern Australia suggest than large deposits are not likely to be found in these areas, but that small deposits of alluvial and lode tin may be found suitable for syndicate or small party operations.

The prospects north of the Daly River and at Fletcher's Gully appear uninviting but tin deposits in the Buldiva-Collia area warrant further investigation. The major problem in the Buldiva-Collia area is that of access but if miners are prepared to return to this area the possibility of establishing an aerodrome and teleradio service should be considered as this would provide them with essential communications through both wet and dry seasons.

5. The Maranboy Goldfield.

The Maranboy Goldfield includes the Maranboy and Yeuralba localities and extends westward to Mount Todd and Wolfram Hill where the Agicondi Goldfield adjoins. Gold, wolfram and tin have been mined from this field but the production of these minerals in the immediate future will be small.

In the Maranboy Area, 40 miles east of Katherine, small deposits of lode tin have been worked at intervals since 1913. Twelve mineral leases are at present held in the area and a Government Battery is still operating. This Battery can treat parcels of gold or tin ore railed from other areas as well as crushings of tin ore mined from the Maranboy deposits.

Four mineral leases are held at Yeuralba approximately 25 miles north of Maranboy and wolfram mining will probably be revived. Small deposits of both tin and wolfram have been worked sporadically in the past and an inspection of the Yeuralba and Maranboy areas is required to assess the future prospects of these areas.

The western portion of the Maranboy goldfield embraces the Mount Todd, Wolfram Hill, Hidden Valley and Driffield Areas but the only immediate prospects appear to lie in the Mount Todd gold mine. Sufficient capital has been raised recently to enable this mine to be opened up and preparations are now in hand to commence production.

6. Deposits of Non-Metalic Minerals.

Barytes has been reported from the Fletcher's Gully area, ochre from near Burrundie, and magnesite from Stapleton Siding.

Specimens of the barytes have been examined and are of good quality but the size of the deposit is not known. The deposit lies south of the Daly River where access is difficult, and this would add considerably to cost of production. Opening up of the deposit could only be regarded seriously at the present time if a large production of high grade barytes could be maintained at low cost.

No information has been found on the quality or size of the ochre deposits near Burrundie, and further investigation is suggested as a high grade ochre would probably find a ready market in Australia.

The magnesite deposits near Stapleton Siding were not investigated but the specimens examined are high quality and Mr. Sargeant of Stapleton Siding stated that analyses have proved the material to be satisfactory for refractory purposes. The mineral has been found in wells and post holes over a considerable area and the deposit would be worth investigating if a profitable market could be found. The highest grade of magnesite realises approximately £2.10.0. per ton Australian ports and hence, unless some special back-loading arrangements could be made, the cost of mining, carting (by rail or road 70 miles to Darwin) and shipping would be prohibitive.

In brief, the present prospects of working deposits of barytes, or magnesite at a profit under the present marketing conditions are poor but the type, size and grade of the ochre depost should be investigated. These deposits would be valuable should local industries be established, such as paint and refractory works which would provide a local market for barytes, ochres, magnesite and other non-metals. However such development is most unlikely while the population of the Northern Terrirory remains small.

7. Prospects of New Discoveries.

It is possible that new ore bodies will be discovered by surface prospecting in the established goldfields, but the prospects for discoveries are brighter in geologically favourable but more remote areas where little prospecting has been carried out in the past. Geologically favourable areas are those in which outcrops of the Brocks Creek Series are associated with granite. One locality in which these conditions are fulfilled lies approximately 40 miles north of Grove Hill, another lies approximately 65 miles north-east of Burrundie (see geological plan). In addition to these, the margins of the Cullen granite have probably not been exhaustively prospected, particularly toward the northern end, and mineral-bearing areas may also be exposed in the valleys and gorges of streams which dissect the Arnhem Land plateau.

In the west the Bamboo Creek area, and the eastern margin of the Litchfield granite, south of the Daly River, have not been exhaustively prospected, but no new prospecting areas can be indicated.

Apart from surface prospecting, new ore bodies may be found in the established goldfields by the application of geological and geophysical methods, followed or accompanied by diamond drilling. The Brocks Creek Series has been strongly folded in most of the mineral-bearing areas and insufficient work has been done on the structural control of ore deposition particularly in the Brocks Creek area.

Detailed structural work was carried out in this area by the Aerial, Geological and Geophysical Survey of Northern Australia in 1939, but the detailed geological plans of the area have not yet been published and the work of attempting to find new ore bodies in this area by structural methods was not completed.

This work should be completed to provide some indication of the results which are likely to be obtained by applying structural ore-finding methods to other similar mineral-bearing areas.

8. Conclusions.

(1) Gold, wolfram, tin, tantalite, silver-lead and copper have been produced in the past from the northern portion of the Territory but a comparatively small production only of tin, tantalite, wolfram and gold can be anticipated in the immediate future.

(2) At present a total of only 39 gold mining leases and 45 mineral leases are held in the northern portion of the Territory and production is now at a very low level. However, present tenure is not a true indication of the potentialities of the mineral fields where mining was seriously interrupted during the latter half of the Second World War.

(3) The principal reasons for the present lack of mining activity are believed to be -

(a) There are no operating mines to offer employment; equipment for individual ventures is hard to obtain, and, owing to the high demand for labour, men can find work entailing less hardship and uncertainty than does mining or prospecting.

(b) On the less remote mineral fields the easily accessible oxidised ore has been extracted from the known deposits. Most of these lode deposits are too small to warrant further exploration by mining companies and without records of the grade of ore below water level such exploration is beyond the means of small syndicates or individuals.

(4) Future prospects of metalliferous mining may be summarised as follows -

i. Major Mines. Only one major gold mine (at Mount Todd) has the established ore reserves and the plant with which to produce. The Fountain Head mine has a plant but the mine is small and only partly developed. There are no other mines with plant or with established ore reserves from which production can be anticipated in the immediate future. However, there are several gold deposits which warrant further investigation and new ore bodies may yet be found by prospecting or by geological and geophysical methods, followed or accompanied by diamond drilling.

ii. Syndicate Mining. The present production of tin, tantalite and gold, both lode and alluvial, is the result of syndicate mining which will remain the principal source of production for some time. Tin and tantalite are produced from a promising field in the Finniss River where at least five parties are operating. Small tin deposits are being worked at Maranboy and wolfram mining will be revived at Yeuralba and possibly at Wolfram Hill. The deposits of alluvial tin at Buldiva would probably attract attention if the localities were less isolated.

(5) Deposits of iron ore are known near Rum Jungle but the quantity and grade of ore available has not yet been established. Deposits of magnesite, barytes and ochre have been noted. The present cost of mining and transport is too high to allow magnesite or barytes to be profitably exploited although a sufficiently high grade of ochre might be profitably mined.

C. PROSPECTS OF PETROLEUM.

Dr. Wade, after his reconnaissance in 1924, reported that there were no prospects of petroleum in the northern portion of the Territory at present under review, (Wade 1924) and subsequent geological work has produced no new evidence on which a more optimistic opinion could be based.

The Palaeozoic sediments of the East Indies Geosyncline offer the best prospects for the occurrence of petroleum and these for the most part are submerged beneath the Timor Sea to the west of the Territory Coastline. However they outcrop in the Burt Range Basin of Western Australia and in the adjacent portion of the Northern Territory and these areas therefore warrant investigation. A company has recently commenced a geological reconnaissance of the Burt Range Basin with a view to examining its oil possibilities.

Upper Palaeozoic sediments are also exposed (as a narrow belt) along the western coastline of the Territory south of the Daly River, but no evidence has been found as yet to suggest that they might contain oil.

D. SUPPLIES OF UNDERGROUND WATER.

Underground water resources in the northern portion of the Territory have not been closely studied in the past because the region receivs a comparatively high rainfall which ranges from 35 to 60 inches per annum and in consequence most of the areas occupied by miners or graziers are adequately supplied with water from water holes and streams or from shallow wells. However, the existing watering facilities were inadequate for surface requirements during the Second World War and many bores were put down-principally along the north-south road and railway line. The Department of the Army has provided a very complete record of these bores and much of the following information is based on bore logs supplied by that Department.

From these bore logs and from the evidence provided by mines and wells it is apparent that supplies of potable ground water are available over the greater part of the region and can be tapped by comparatively shallow bores. With the exception of sites which are topographically unsuitable, such as the crests of ridges and the tops of some of the mesas, supplies of sub-artesian water can probably be obtained at most places at depths of less than 300 feet. However, the depths at which significant supplies are found depend largely on geological factors and consequently geological advice is advisable in the location of bores particularly in areas occupied by Pre-Cambrian or granitic rocks.

The greater part of the region in which bores are likely to be required is occupied by metamorphics of the Brocks Creek Series by Cambrian sediments or by granitic rocks.

Many Army bores were put down in metamorphics of the Brocks Creek Series and very few of these failed to produce sub-artesian water. Quantities of potable water ranging from 500 to 2,000 gallons per hour were pumped from depths which ranged from 25 to 300 feet below ground level. In most places major supplies were drawn from depths of 100 to 200 feet. There appears to be no difficulty in obtaining supplies of about 1,200 gallons per hour by pumping from this depth, although fluctuation must be expected from wet to dry seasons. The static water level in old mine workings and in wells in areas occupied by the Brocks Creek Series along the railway line commonly lies between 20 and 50 feet below the surface and similar static water levels were noted in the Army bores. Underground water in the Brocks Creek Series is contained in fractures and joints in the rock rather than in porous strata and in many places bores could be sited to penetrate the most favourable, shattered beds.

Cambrian rocks consist largely of limestone and sandstone with varying degrees of silicification and underground water is contained in porous limestone and sandstone aquifers as well as in fractures in the more silicified rock types. Between the north-south road and the Daly River and to the south-east of Katherine quantities of up to 1,800 gallons of water per hour have been obtained by pumping from depths which range from 70 to 170 feet. It is probable that artesian water can be obtained in some Cambrian areas, particularly along the Daly River, but more information will be required on the structure of the Cambrian sediments before artesian basins can be delineated. At least one bore in the vicinity of Manbaloo encountered artesian water in limestone at a depth of 91 feet below the surface. The bore flowed at the rate of 800 gallons per hour but 4,000 gallons per hour were produced by pumping. This artesian basin may only be small but similar basins could probably be found in other Cambrian areas.

In general, supplies of sub-artesian water should be readily obtainable throghout areas occupied by Cambrian sediments and the quantities available should be comparable with those obtained from the Pre-Cambrain rocks.

According to the Army bore logs, supplies of underground water are not as readily obtainable in areas of granitic rocks as in the areas of Cambrian and Pre-Cambrain sediments discussed above. In granitic areas underground water is generally stored in joints and fractures and in weathered sections of the rocks and the yield at any bore site will, therefore, depend largely on the extent to which such fractures are developed in the underlying rock and in the shape of the under surface of weathered areas. Supplies of sub-artesian water comparable with those encountered in areas occupied by the Brocks Creek Series should be obtainable from granitic areas if the bore sites are located in strongly jointed rocks.

Areas which are occupied by sediments of the Mullaman Group include the low-lying country fringing the north-west coastline and the table-topped hills which are found farther inland. Supplies of sub-artesian water up to 1,500 gallons per hour have been obtained from bores in the vicinity of Darwin but this water is not drawn from the Cretaceous sediments but from the Pre-Cambrian metamorphics which underlie the Mullaman Group. Some water is probably stored in the basal beds of the Mullaman Group, but the relatively impermeable cap rock which is commonly found overlying the Cretaceous sediments has doubtless caused an unusually high run-off and has acted in places as a seal over any underlying porous beds. Very few springs were noted at the base of mesas composed of sediments of the Mullaman Group and this is probably due to the impervious character of the porcellanite cap rock.

E. RECOMMENDATIONS.

It is suggested that the mining industry can best be assisted in the following ways:-

1. Technical Assistance.

A commendable policy of financial assistance to miners is in force in the Northern Territory but most of the men at present engaged in mining in the Darwin District require technical assistance in prospecting, or in sampling and developing mineral deposits or in selecting and operating mining plants. Such assistance could best be supplied by a geologist and an Inspector of Mines stationed in the northern portion of the Territory.

2. Geological and Geophysical Investigations.

The reports of the Aerial, Geological and Geophysical Survey of Northern Australia and some of the older records, provide detailed geological accounts of many of the mines and of some of the mining localities in this region. However, there is no report in which all the relevant information and recommendations are compiled to provide a complete summary of the mining prospects in each of the recognised districts. It is suggested that such summary reports should be compiled as the first step toward assessing the present potentialities of the mineral fields. In these reports, it should be possible to delineate those areas in which further prospecting or field work is warranted and to indicate those mines and leases on which recommendations made by previous workers have not been carried out.

(Note: Plan already agreed to between the Departments of the Interior and Supply and Shipping will ensure that the subjects dealt with in Recommendations 1 and 2 are adequately covered).

3. Government Treatment Plants.

A Government battery is still operating at Maranboy, but there are no other mineral fields on which the erection of a central treatment plant can be recommended at present. Future development may warrant the re-instalment of a Government battery in the Pine Creek-Adelaide River area but until sufficient tribute ore is in sight, small parcels of high-grade ore can be treated at Maranboy, under the cartage-subsidy scheme, or, by private arrangements, at the Fountain Head Mine.

A central treatment plant cannot yet be recommended in the Finniss River district, but future development may disclose sufficient tribute ore.

4. Communications.

Consideration should be given to improvement of facilities for transport and communication with the outlying mining fields, to encourage the growth of stable mining communities, and it is suggested that one method of doing this would be by inauguration of subsidised aerial and teleradio services in those areas which are isolated during the wet season.

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23/4/47.

TABLE 1.

STRATIGRAPHY.

AGE	NAME & CLASSIFICATION	SUB-DIVISION	DESCRIPTION	THICKNESS	CORRELATIO
Quaternary	- -	- -	River alluvials - coastal black soil plains Younger laterites	-	-
Tertiary	-	-	Older laterites No sediments definitely identified.	10' +	-
Lower Cretaceous	Mullaman Group	Darwin formation	Shales and sandy shales with Lower Cretaceous fossils	50' + up to 210'	Portion of Winning Ser[illegible]s, Western Aus[illegible]a
Upper Jurassic		-	Poorly consolidated sandstones with some conglomerates		
Permian	Port Keats Group	-	Sandstones, shales and limestones with some coal seams	730' +	
Upper Pala[illegible]oic. (Devonia[illegible] Permian bu[illegible] [illegible]ationship to P[illegible] Keats Group no[illegible] [illegible]stablished.)	Elliot Creek formation	-	Sandstone, shales and limestone	probably less than 500'	

AGE	NAME & CLASSIFICATION	SUB-DIVISIONS	DESCRIPTION	THICKNESS	CORRELATION
Lower Cambrian	Florina Group	-	Sandstones, probably with some limestone beds	-	Mt. Elder Series. Kimberley Division, Western Australia.
	Daly River Limestone Group	-	Limestones, sandstones and shales.	-	Negri Series. Kimberley Division, Western Australia. Templeton Series, Queensland.
Upper Proterozoic	Edith River Volcanics Maude Creek Volcanics Collia Creek Volcanics	- - -	Lavas and pyroclastics		Probably contemporaneus with Lower Cambrian. Volcanics of Kimberley Division Western Australia.
Upper Proterozoic	Buldiva Group	-	Mainly quartzites, sandstones and grits with some shales shallow water markings characteristicly developed	Probably several thousand feet.	Nullagine Series, Western Australia.
INTRUSION OF THE LITCHFIELD GRANITE AND THE CULLEN GRANITE.					
Lower Proterozoic	Brocks Creek Series	Golden Dyke Group	Sandstones, conglomerates, quartzite, slate and intrusive amphibolites.	2,000'+ (15,000 + total)	Mosquito Creek Series of Western Australia.
		Pine Creek Group	Slate, sandstones, tuffs.	?	
		Muldiva Group	Slates, phyllites and schists		

TABLE II.

Summary of Mining Tenure in the Northern Portion of the Northern Territory.

Goldfield and Locality	No. of Gold Mining Leases	Area (Acres.)	No. of Mineral Leases	Area (Acres.)	Total No. of Leases	Total Area Acres
Agicondi Goldfield						
Pine Creek	6	200				
Frances Creek	3	60				
Yemelba	1	10				
Total	10	270			10	270
Woggaman Goldfield						
Bridge Creek	1	20				
Shackle Creek	2	25				
McKinley River	1	20				
Cosmo Howley	3	45				
Fountain Head	2	30				
Grove Hill	1	20				
Batchelor	15	300				
Mt. Wells			3	160		
Bamboo Creek			5	140		
Walker Creek			6	210		

MINERAL PRODUCTION NORTHERN TERRITORY, NORTHERN (DARWIN) DISTRICT.

(Partly adapted from table given as supplement to Aerial, Geological and Geophysical Survey of Northern Australia report for period ended 30th June, 1940).

	GOLD Bullion		TIN CONCENTRATES		WOLFRAM CONCENTRATES		COPPER CONCENTRATES		SILVER LEAD		TANTALITE CONCENTRATES		SILVER ORE		TOTAL VALUE
	oz.	£	tons	£	tons	£	tons	£	tons	£	tons	£	tons	£	
1869 to 17th Aug., 1880	15000 ≠	52500	–	–	–	–	–	–	–	–	–	–	–	–	52,500
1880		680	–	–	–	–	–	–	–	–	–	–	–	–	680
1881		111945	–	–	–	–	–	–	–	–	–	–	–	–	111,945
1882		80720		1650	–	–		206	–	–	–	–	–	–	82,576
1883		77195		871	–	–		–	–	–	–	–	–	–	78,066
1884		77935	)113	814	–	–		–	–	–	–	–	–	–	78,749
1885		70414		135	–	–	)1411	13775	–	–	–	–	–	–	84,324
1886		63139		78	–	–		9492	–	–	–	–		303	73,012
1887		68774		1322	–	–		5888	295	13675	–	–		–	89,659
1888		34802		3159	–	–		1360		15463	–	–		1491	56,275
1889		47339		4360	–	–		11565	)369	2310	–	–		3849	69,423
1890		80524		6140	–	–		4600		647	–	–		3720	95,631
1891		98149		1870	–	–	)3135	3619		4120	–	–		20	107,778
1892		109228	)546	2433	–	–		2155	–	–	–	–	)710	1640	115,456
1893		108110		1595	–	–		1190	–	–	–	–		150	111,179
1894		109621		1251	–	–		1204	–	–	–	–		115	116,999
1895	)605954	102782		1815	–	–		410	–	–	–	–		–	107,645
1896		81200		530	–	–	–	–	–	–	–	–		1230	83,692
1897		81024		–	–	–	–	–	–	–	–	–		–	81,024
1898		84744		100	–	–	–	–	–	–	–	–		–	84,844
1899		60648	5	180	–	–	–	–	–	–	–	–		–	60,828
1900		61089	17	774	–	–	438	14095	–	–	–	–		523	76,48
1901		61187	80	2105	2	175	429	2345	–	–	–	–		20	65,832
1902		61379	120	5985	–	–	142	1813	–	–	–	–	–	–	69,177
1903		41629	171	10773	–	–	3	55	–	–	–	–	–	–	52,457
1904		40926	366	27360	28	2500	346	27029	167	1386	–	–	–	–	99,201
1905		47246	288	25877	25	2573	/	16336	130	1303	–	–	–	–	93,335
1906		33637	398	33837	108	7144	955	48760	232	2355	2.10	140	–	–	126,077
1907		18279	436	41365	91	11451	832	15031	297	2093	–	–	–	–	88,219
1908		21095	441	35876	35	1925	525	7968	2	30	–	–	–	–	67,194
1909		24148	220	32741	32	4105	/	3742	–	–	–	–	–	–	64,736
1910	7138	21711	364	31113	70	6686	97	1196	–	–	–	–	–	–	60,706
1911	8839	26702	239	22900	50	4048	164	1470	–	–	–	–	–	–	55,145
1912	7414	20150	271	27001	39	3330	377	3998	107	820	–	–	–	–	55,299
1913		13250	258	25526	11	3140	41	482	308	2228	–	–	–	–	44,626
1914/15	)6357	14538	160	20745	20	5601	)1677	11860	90	550	–	–	–	–	53,734
1915/16		3861	140	14700	)79	6083≠		8162	)178	1068	–	–	–	–	30,013
1916/17		3677	270	27120		–	48	5517		275	–	–	–	–	27,395
1917/18	525	2229	245	41432	100	17600≠	619	9648	26	200	–	–	–	–	61,461
1918/19	900	3521	162	30021	70	12110≠	159	2349	12	132	–	–	–	–	45,784
1919/20	939	3192	179	27610	72	11597	67	780	17	299	–	–	–	–	42,798
1920/21	304	1042	83	7793	–	–	–	–	–	–	–	–	–	–	8,800
1921/22	145	488	79	5891	–	–	–	–	–	–	–	–	–	–	6,050
1922/23	207	714	136	13887	–	–	–	–	–	–	–	–	–	–	14,468
1923/24	816	2988	97	12855	–	–	–	–	–	–	–	–	–	–	15,124
1924/25	519	1939	110	15966	–	–	–	–	191	617	–	–	–	–	18,897
1925/26	142	537	98	15852	–	–	–	–	61	594	–	–	–	–	16,897
1926/27	123	468	109	18755	–	–	–	–	31	379	0.07	8	–	–	19,609
1927/28	114	431	79	10828	–	–	–	–	2	22	0.33	66	–	–	11,346
1928/29	143	553	59	6958	–	–	–	–	12	79	0.97	207	–	–	7,796
1929/30	16	57	31	3345	1	–	–	–	7	37	2.70	1013	–	–	5,131
1930/31	593	2445	33	2331	–	–	–	–	8	160	1.42	450	–	–	5,386
1931/32	763	3465	26	2322	–	–	–	–	–	–	0.76	240	–	–	6,027
1932/33	712	4488≠	25	2519	–	–	–	–	24	411	–	–	–	–	7,418
1933/34	232≠	1642≠	66	9566	1	76	–	–	8	11	0.38	65	–	–	11,360
1934/35	863fine	5954≠	38	6036	1	175	–	–	–	–	1.07	264	–	–	12,429
1935/36	633	4091	30	4176	–	–	–	–	–	–	–	–	–	–	8,267
1936/37	364	2632	46	7696	3	511	–	–	–	–	–	–	–	–	10,839
1937/38	284	2088	18	2972	14	3252	–	–	26	328	0.28	180	–	–	8,820
1938/39	258	1903	26	4220	11	1728	–	–	–	–	–	–	–	–	7,851
1939/40	448	3903	26	4208	9	1739	–	–	–	–	–	–	–	–	9,850
1940/41	–	–	20	3416	4	660≠	–	–	–	–	–	–	–	–	4,076
1941	–	–	22	4041	–	–	–	–	–	–	–	–	–	–	4,041
1942	–	–	32	6627	–	–	–	–	–	–	–	–	–	–	6,627
1943	–	–	26	5594	5	1695≠	–	–	–	–	0.58	–	–	–	7,289
1944	–	–	11	2086	6	2034≠	–	–	–	–	0.12	–	–	–	4,120
1945	–	–	23	5026		122≠	–	–	–	–	–	–	–	–	5,148
1946	–	–	15	1364	–	–	–	–	–	–	–	–	–	–	1,364
	660,745	2,165,747	6853	699,494	885	112,060	11,465	238,100	2,600	51,592	10.78	2,633	710	13,061	3,266,984

≠ Estimated.

/ Not recorded.

This table gives, so far as it is possible to trace from records at present available production from the Northern (Darwin) District of the Northern Territory. Production from Tanami and Arltunga is known to be included in figures for early years, but exact quantities and values are not available.