DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1975/39

PROGRESS REPORT, ALLIGATOR RIVER PARTY NT, 1972
(OENPELLI REGION)

by

R.S. Needham, P.G. Smart, & A.L. Watchman

Record 1975/39

PROGRESS REPORT, ALLIGATOR RIVER PARTY NT, 1972
(OENPELLI REGION)

by

R.S. Needham, P.G. Smart, & A.L. Watchman

CONTENTS

TEXT-FIGURES

TEXT-PLATES

PLATES

SUMMARY

This Record describes the results of fieldwork by the Alligator River Party during 1972 in the Oenpelli district of the Alligator Rivers uranium field. 1:50 000-scale maps (compilation sheets) of the geology of the Junction Bay 1:100 000 Sheet area, and parts of the Goomadeer, Wellington Range, Oenpelli, and East Alligator 1:100 000 Sheet areas accompany the text.

The Myra Falls Metamorphics have been remapped as the outer zones of the Nimbuwah Complex, whose outer margin is defined by the onset of metamorphic differentiation within a gradational metamorphic sequence. The Nimbuwah Complex is a migmatite complex composed of a central granitoid core, a concentric zone of migmatites, a concentric zone of lit-par-lit gneisses, and an outer transitional zone of schist and gneiss. The Granitoid Core is composed mostly of homogeneous and foliated pink and white granitoid rocks; porphyroblastic diatexite is common towards the margins of the core, and generally displays linear contacts with the granitoid rocks. The Migmatite Zone is composed of rocks displaying a wide array of structures formed by various associations between leucosome, melanosome, and palaeosome. These rocks are invaded by porphyroblastic diatexite of the Granitoid Core towards the inner margins of the zone. The Lit-par-lit Gneiss Zone is characterized by the development of leucosome in schist and gneiss; amphibolite within the Complex is mostly restricted to this zone. The schist and gneiss grade outwards into rocks of the Transitional Zone - mostly quartz muscovite schist - which are only incipiently migmatized. The Transitional Zone grades out into unmigmatized schist and phyllite of the Fisher Creek Siltstone near Oenpelli.

The Nimbuwah Complex represents an orogenic centre within an extensive Lower Proterozoic geosyncline. The eastward extension of the Complex is covered by Carpentarian and Cambrian sandstone and shale, and the northern extension is hidden under the Arafura Sea.

The 'Oenpelli Dolerite' intrudes the Fisher Creek Siltstone and the Nimbuwah Complex; it is a symmetrically differentiated intrusion derived from an alkali basalt parent magma, and forms an undulating sheet or perhaps a series of lopoliths, about 250 m thick, extending from Aurari Bay to Jim Jim Falls. The differentiated phases are a chilled margin, porphyritic olivine dolerite, gabbroic pegmatite, ophitic dolerite (grading to ophitic gabbro), and granophyric dolerite. Hornfelsing is apparent where the dolerite intrudes the Fisher Creek Siltstone and the outer zones of the Nimbuwah Complex. Where the dolerite intrudes the inner zones of the Complex, hornfelsing is absent; instead, the dolerite has assimilated the country rock.

The Nimbuwah Complex is intruded by peralkaline phonolite dykes in a small area near the headwaters of Jungle Creek. The dykes are undeformed, and have sharp contacts with the country rock; they were probably emplaced later than the 'Oenpelli Dolerite'.

The Goomadeer Volcanic Member, formerly described as a basal member of the Kombolgie Formation, was incorrectly photo-interpreted; the rocks in the areas mapped as Goomadeer Volcanics are now known to be composed of Nimbuwah Complex gneiss and Oenpelli Dolerite.

The Kombolgie Formation is composed of cross-bedded and ripple-marked medium to coarse quartz sandstone with minor conglomerate and siltstone. It is divided into upper and lower units by the Nungbalgarri Volcanic Member, a thin extensive sheet of basalt which is amygdoloidal in places; intercalated siltstone and sandstone indicate more than one flow. The sandstone overlying the volcanic member is more homogeneous than that below, and contains fewer conglomerate and pebble beds.

The Kombolgie Formation is unconformably overlain to the east by Cambrian strata, of which only the Buckingham Bay Sandstone (medium-grained white quartz sandstone) crops out.

Much of the central and far western parts of the survey area are covered by subhorizontal sheets of Lower to Upper Cretaceous Bathurst Island Formation (fossiliferous marginal marine sandstone and siltstone). Small mesas of undivided Lower Cretaceous freshwater sandstone and siltstone rise above the Arnhem Land Plateau, in the south of the area.

Cainozoic sediments form a veneer over most of the older units. A recent drop in sea level has resulted in widespread erosion of Cainozoic valley deposits.

The structure of the area is dominated by the roughly concentric arrangement of Lower Proterozoic metasediments around the Nimbuwah Complex. Folding becomes less intense farther west, and in the East Alligator Sheet area a uniform easterly dip predominates. In the Survey area, the 'Oenpelli Dolerite' forms a series of shallow ellipsoidal basins whose rims, during early Kombolgie sedimentation, formed prominent ridges that caused the Formation to be deposited in a series of wide shallow basins. The rate of erosion of the sandstone has been greatest in zones of extensive jointing developed in the sandstone above the dolerite ridges during warping, so that today there is an obvious spatial association between the Kombolgie scarp and the dolerite. The scarp is also commonly fault-controlled, especially east of the Goomadeer River, where there are vertical displacements of at least 100 m. The concentric structures of the Nimbuwah Complex are overlapped in the northeast by the Arafura Basin, an arcuate shallow depression in which the Cambrian Wessel Group was deposited.

The Nabarlek uranium deposit and several uranium prospects lie within the Nimbuwah Complex. The Nabarlek and Black Rock prospects both lie on north-northwest-trending structures along which the country rocks have undergone retrogressive metamorphism. The genesis of uranium is probably associated with the formation of the Nimbuwah Complex, the uranium being 'sweated out' of the Lower Proterozoic rock pile during migmatization, and deposited in favourable dilatational structures. Other possible modes of origin are discussed.

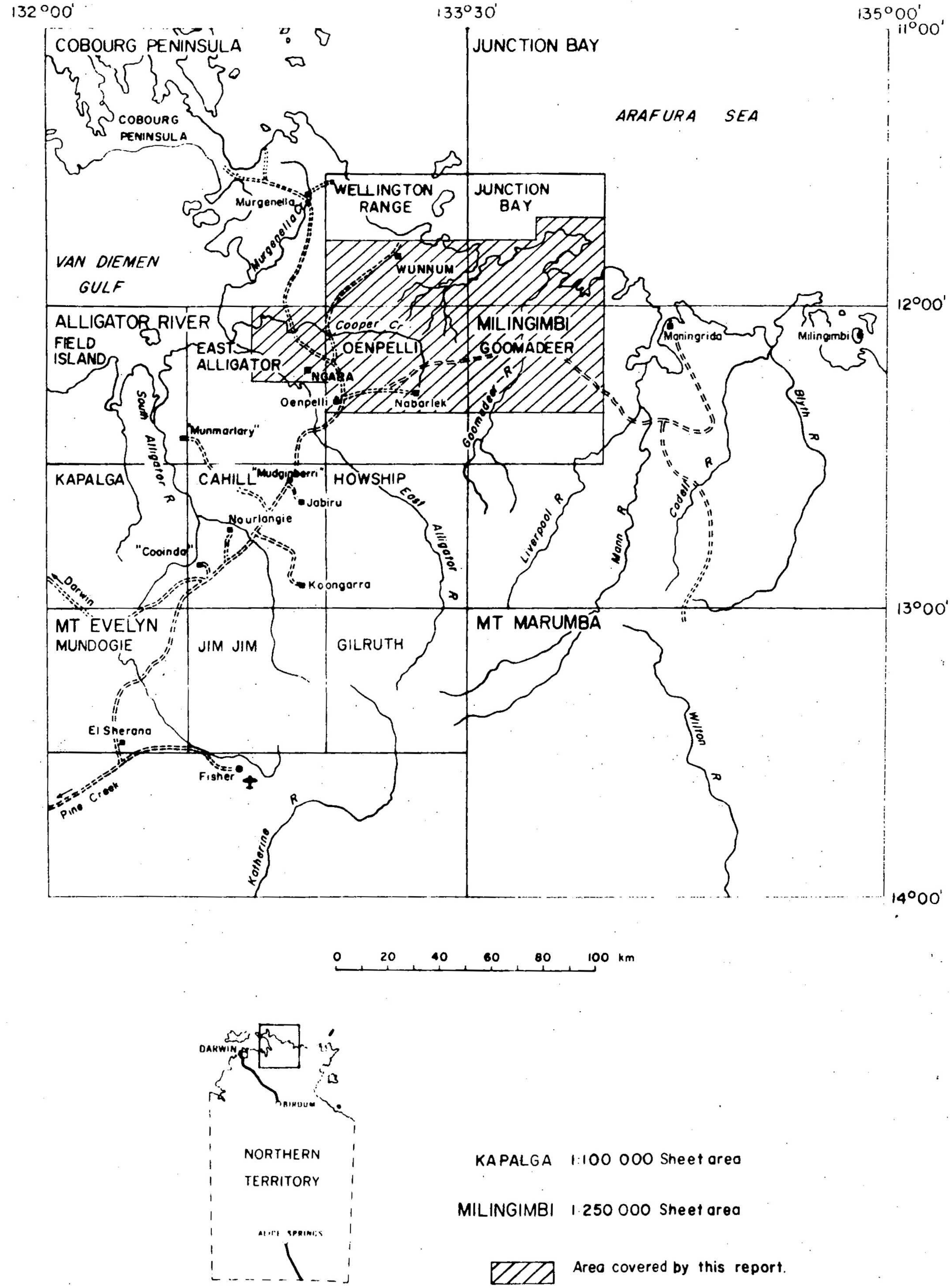


Fig. 1 Location map.

INTRODUCTION

During 1972 a Bureau of Mineral Resources (BMR) field party continued semidetailed mapping of the Alligator Rivers uranium field. This Record is an account of part of the 1972 fieldwork, and includes 1:50 000-scale compilation sheets of the geology of the following 1:100 000 Sheet areas: East Alligator NE; Goomadeer NW, NE, and part of SW and SE; Junction Bay (all); Oenpelli NE, NW, and parts of SE, SW: and Wellington Range SE, SW. Work done during 1972 in the Jim Jim area is reported separately (Needham et al., 1975). Proposed and approved changes in stratigraphic nomenclature are appended.

Traverses in light four-wheel-drive vehicles and on foot were made over the survey area from late July until late October from a base camp situated on Cooper Creek 3 km south of Nimbuwah Rock. Four traverses were drilled in the Oenpelli Sheet area by a trailer-mounted Gemco auger drill.

Field observations were plotted onto RC8 (1:16 000-scale) aerial photographs; detailed interpretation of these photographs was later transferred to overlays on 1:50 000-scale enlargements of RC9 (1:83 000-scale) aerial photographs, and was then drafted onto 1:50 000-scale corrected bases drawn from the RASC topographic bases.

Location and access

The location of the survey area is shown in Figure 1. The western margin of the area lies 330 km east of Darwin, and the base camp, situated centrally within the area, was 400 km by road from Darwin.

Access to the area is by the Darwin-Oenpelli road (a graded dirt road), and then by dirt tracks radiating from Oenpelli north to the Murgenella forestry camp and east to Maningrida, and to various exploration camps such as Wunnum, Nabarlek, and Ngara.

Previous investigations

Investigations before the 1960s are listed by Walpole et al. (1968) and Rix (1965). BMR field parties conducted reconnaissance mapping in the area between 1953 and 1957 (the Alligator River 1:250 000 Sheet area; Dunn, 1962) and in 1962 (the Junction Bay and Milingimbi 1:250 000 Sheet areas; Rix, 1964, 1965).

Since 1969, exploration companies have been active in the area prospecting mainly for uranium and manganese. Reports of their activities are lodged with the Mines Branch, Darwin, Northern Territory.

PHYSIOGRAPHY

The dominant physiographic unit of the survey area is the Arnhem Land Plateau, whose edge forms a sheer scarp up to 70 m high west of the King-Cooper Divide (Figure 2). The plateau is markedly dissected: the main watercourses may form gorges 100 m deep, and tributaries are commonly incised along joints and faults.

East of the King-Cooper Divide the plateau margin is rarely marked by a prominent scarp, and the plateau forms part of the Arafura Fall. This unit includes undulating hilly country and broad soil-covered plains, mostly developed over the Nimbuwah Complex. Drainage of the unit is to the Arafura Sea.

West of the King-Cooper Divide drainage is to the Van Diemen Gulf. This area is the far northeastern part of the Northern Plains unit, which consists of the remnants of a middle Tertiary peneplaned and lateritized surface (the Koolpinyah surface, Story et al., 1969) partly covered by younger colluvial and outwash sands (Dunn, 1962). It is underlain by Fisher Creek Siltstone and Nimbuwah Complex rocks, and eastwards grades into Arafura Fall type topography.

The Coastal Plains extend up to 60 km inland, and form an area of low relief mostly underlain by lateritized Mesozoic and older rocks. Cainozoic sand, soil, and alluvium generally mask bedrock, except along incised watercourses.

The Tidal Flats form part of the Coastal Plains, and are developed along the lower reaches of rivers and creeks, or where minor creeks have been banked up by the growth of coastal dunes.

Coastal Sand Dunes of the Coastal Plains generally border the present coastline; those occuring a few kilometres inland are generally associated with Quaternary estuarine evolution.

The Estuarine Plains is a similar physiographic unit to the Tidal Flats developed adjacent to the Arafura Sea, but is instead developed along large estuaries and associated flood plains draining into the Van Diemen Gulf. The Estuarine Plains extend inland as far as 100 km.

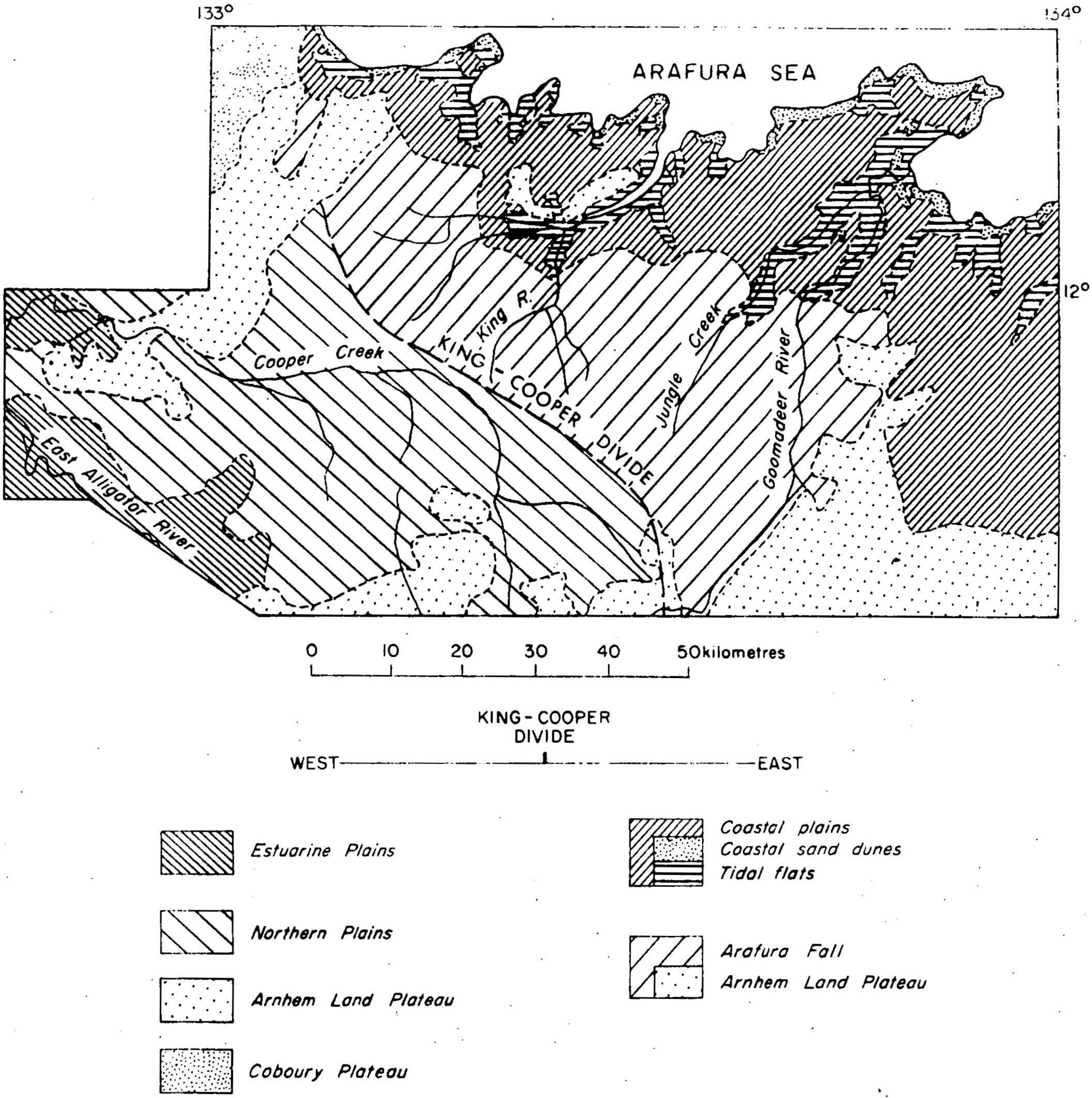


Fig. 2 Physiographic sketch map.

The Cobourg Plateau, in the far northwest of the survey area, is an extensive unit occupying most of the base of Cobourg Peninsula. It is a sandy plateau underlain by lateritized Mesozoic strata, which have been slightly tilted to form cliffs along the eastern shore of the peninsula; drainage is almost entirely westerly, into the Van Diemen Gulf.

STRATIGRAPHY

Walpole et al. (1968) considered outcrops of schist, phyllite, and quartzite near Oenpelli to be of Archaean age, and assigned to them the name Myra Falls Metamorphics. However, these rocks are continuous with phyllite and shale of the Fisher Creek Siltstone, and grade eastwards into Nimbuwah Complex migmatites. Consequently we have discontinued the name Myra Falls Metamorphics, and consider that these metamorphic rocks represent increasing grades of metamorphism of Lower Proterozoic sediments adjacent to, and within, the Nimbuwah Complex. The boundary of the Nimbuwah Complex is defined byy the appearance of quartz-feldspar leucosome which forms lenses and bands parallel to the schistosity in the metamorphic rocks - i.e., onset of metamorphic differentiation forming lit-par-lit gneiss.

The Complex is a migmatite massif, composed predominantly of foliated granitoid rocks, a variety of migmatites displaying interpenetration fabrics, and augen gneiss and lit-par-lit gneiss. It is invaded by pegmatite and aplite dykes, which are late-stage anatectic rocks. The similarity between the Nimbuwah Complex and the Nanambu Complex (Needham & Smart, 1972) is obvious, and they may be exposed parts of one large orogen, which was formed by wide-scale migmatization of the Lower Proterozoic sedimentary pile. The inclusion of Archaean basement material as a nucleus within the orogen - i.e., fitting the mantled gneiss dome theory of Eskola (1948) - is possible, however, and details of the genesis of the Complexes is still a subject for discussion.

The older rocks in the area are intruded by an extensive sub-horizontal layered dolerite which eextends from Graveside Gorge in the south (Needham et al., 1973, 1975) to the Wellington Range Sheet area. The dolerite forms a series of shallow basins, which may be part of a large sheet-like body, or may be individual lopoliths. We have named it the 'Oenpelli Dolerite'* and consider it to have been intruded after the Nimbuwah Complex was formed, or at least before the Complex completely cooled. The dolerite has been drilled through at the Nabarlek and Black Rock prospects, and a standard layered

*Name reserved by Territories Division Stratigraphic Nomenclature Subcommittee, but not yet approved.

sequence has been recognized; it averages about 250 m thick, but may thicken towards the centre of the basins.

The Nimbuwah Complex is extensively intruded by phonolite dykes in a small area near the headwaters of Jungle Creek. We have named these rocks the 'Maningkorrirr Phonolite'*, and note their similarity to the 'Mudginberri Phonolite'*, described by Needham et al. (1972).

Ruker (1962) and Rix (1965) recognized the Goomadeer Volcanic Member by photogeological interpretation as a basal unit to the Kombolgie Formation, and regarded it as a lens resting unconformably on rocks of the Nimbuwah Complex. We have found, however, that this interpretation was incorrect; the smooth grey photopattern is representative of gneiss, migmatite, dolerite, or brown soil. Agate in one creek within the photo-unit was found to be derived from the Nungbalgarri Volcanic Member upstream.

The Kombolgie Formation outcrop pattern is rigorously controlled by faulting throughout the survey area, especially in the Goomadeer Sheet area. Vertical movement is generally no more than about 60 m, some lateral displacements of Lower Proterozoic units can be seen, but no such displacement of the Kombolgie Formation is evident.

Units of the Wessel Group form curvilinear cuestas in the far east of the survey area, and outcrop is generally confined to the scarp face. Only outcrops of Buckingham Bay Sandstone were visited during the year.

Flat-lying deeply leached and ferruginized Mesozoic strata cover much of the central and eastern parts of the survey area; elsewhere Cainozoic sand and alluvium form an almost continuous veneer over Lower Proterozoic strata, whose outcrop is confined to incised creeks and isolated hills.

Figure 3 is a generalized geological map of the survey area.

FISHER CREEK SILTSTONE (Elf)

The Fisher Creek Siltstone is best exposed along a scarp near Oenpelli Mission, and also as rubble-covered hills and deeply weathered exposures in incised creeks. A few exposures are adjacent to ridges of quartz breccia.

*Name reserved by Territories Division Stratigraphic Nomenclature Subcommittee, but not yet approved.

13

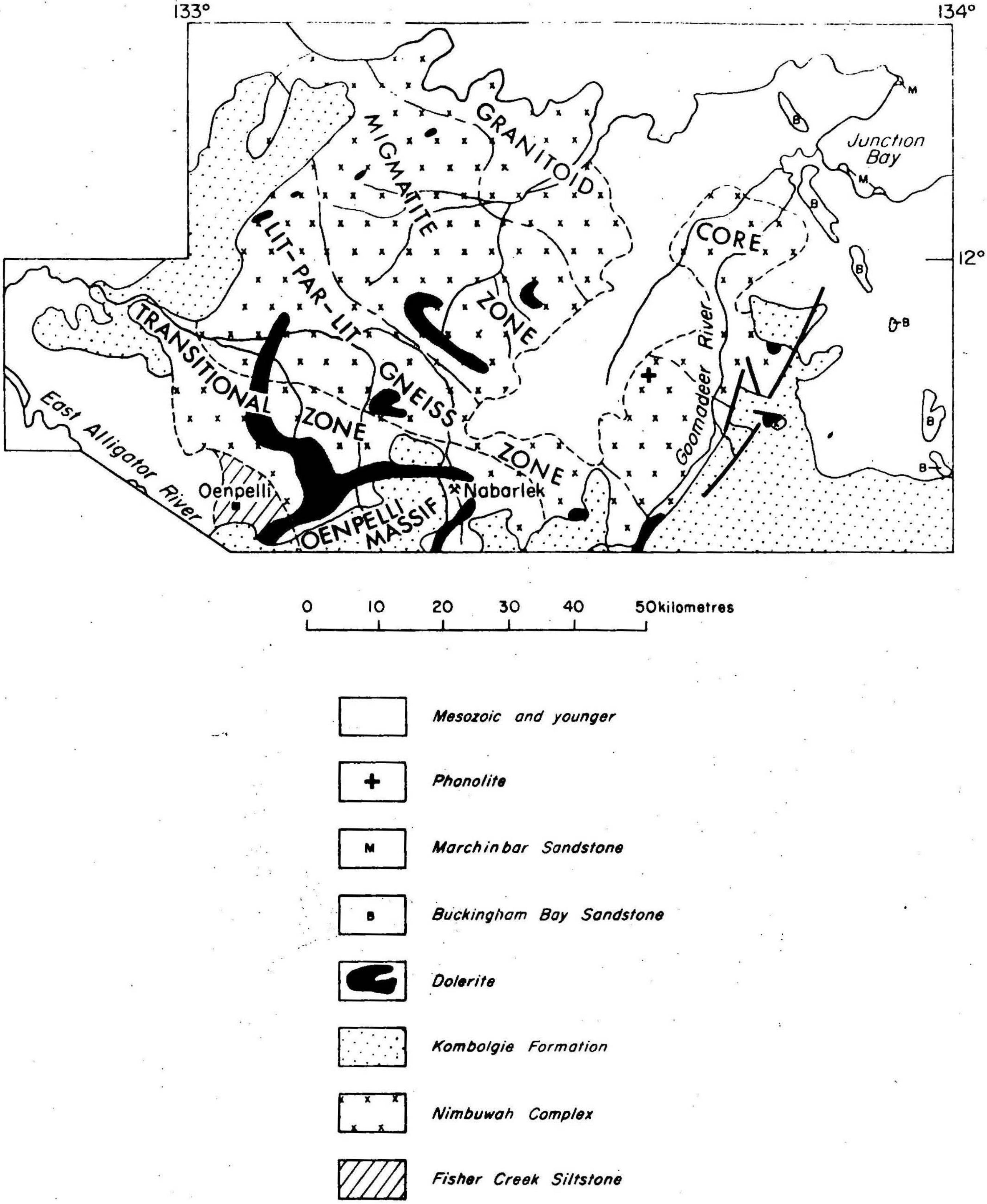


Fig. 3 Generalized geological map

Steep easterly dips prevail in the East Alligator NE Sheet area, but shallow southeasterly dips predominate along the northern margin of the Oenpelli Massif, where tight recumbent isoclinal folding is evident.

The Fisher Creek Siltstone of the Oenpelli district is composed predominantly of quartz-mica schist, quartz-chlorite-mica schist, micaceous quartzite, and quartzite. It is transitional into higher-grade migmatite of the Nimbuwah Complex to the east, and lower-grade metamorphics to the west and south. The appearance of leucosome (quartz-feldspar augen, pods, or bands) with increasing metamorphism defines the boundary of the Nimbuwah Complex. Aeromagnetic patterns (Horsfall & Wilkes, in prep.) and results of auger drilling (see Appendix 2, Traverses 10, 11) suggest that most of the Fisher Creek Siltstone is underlain by 'Oenpelli Dolerite'. Chloritization adjacent to the dolerite obscures the true regional metamorphic grade. However, it appears that the grade increases from upper greenschist in the west and south to lower amphibolite facies nearer the Nimbuwah Complex. In places the grade reaches the staurolite-almandine-amphibolite subfacies adjacent to the Complex, and is similar to the grade of Koolpin Formation equivalent rocks adjacent to the Nanambu Complex (Needham & Smart, 1972).

NIMBUWAH COMPLEX

The Nimbuwah Complex is masked by overlying strata in the north and east, but where it is exposed (within the Wellington Range, Oenpelli, Junction Bay, and Goomadeer Sheet areas) four broadly concentric zones have been mapped (Fig. 3).

All of the rock types within the Complex are considered to be products of high-grade regional metamorphism and metamorphic differentiation; the core is a product of anatexis. The nomenclature used in the text for migmatites is based on that of Mehnert (1968).

Granitoid Core (Plz_1)

In the northeast of the Complex, exposures are predominantly of foliated to homogeneous granitoid rocks (diatexites - rocks formed by high-grade anatexis, which involves melting of all the rock components) cropping out as low pavements or boulders on lightly wooded sandy plains (Text - Plate 1). The rocks are medium to coarse, and consist of quartz, plagioclase, orthoclase, microcline, and biotite, with or without hornblende. The feldspars are usually clouded by fine-grained deuteric alteration products - generally sericite with probable clinozoisite and epidote. Biotite and hornblende are commonly altered completely or incipiently to chlorite. Most of the biotite contains haloed inclusions of zircon. Accessory minerals, apart from zircon, are muscovite, skeletal magnetite, epidote, apatite, tourmaline, and sphene.

Within the Granitoid Core at lat. 1°02'S, long. 133°49'E, an exposure of quartz-muscovite schist forms an isolated hill on the east bank of Wurugoij Creek. Although the schist appears to be a low-grade metamorphic rock, its granoblastic texture suggests that it may be sheared foliated granitoid country rock. The exposure may then represent an extension of the Goomadeer Fault (see Map Plate 10).

Towards the margins of the Granitoid Core, contacts between a medium to coarse-grained pink granitoid diatexite and a porphyroblastic diatexite, characterized by euhedral feldspar crystals up to 5 cm across (Text-Plate ii), are mostly sharp. Although both types are texturally different, they are petrographically similar. In many outcrops of porphyroblastic diatexite a faint foliation resulting from the rough alignment of feldspar porphyroblasts is evident.

Xenoliths of intermediate to basic composition, ranging from several centimetres to about 20 m in diameter, are abundant within the porphyroblastic diatexite. Typically the xenoliths are subrounded, reflecting partial assimilation by the surrounding diatexite. The xenoliths are composed of plagioclase, biotite, minor pyroxene (with exsolution lamellae and alteration to uralite), quartz, and accessory apatite, and appear to be fragments of 'Oenpelli Dolerite,' as their texture, grainsize, and mineralogy are similar to the finer grained phases of the 'Oenpelli Dolerite'. The xenoliths are confined to two belts in the porphyroblastic diatexite, and appear to form easterly extensions of the 'Oenpelli Dolerite' between Cooper Creek and the King River. However, some may be remnants of the parent rock from which the porphyroblastic diatexite was derived.

Migmatite Zone (Plz_2)

A zone of structurally complex migmatites, up to 30 km wide, which surrounds the Granitoid Core, is formed by various associations of leucosome, melanosome (the newly formed leucocratic and melanocratic parts of a migmatite), and palaeosome (the parent rock of a migmatite). The inner margin of the zone is rarely exposed, but those outcrops that have been seen show that

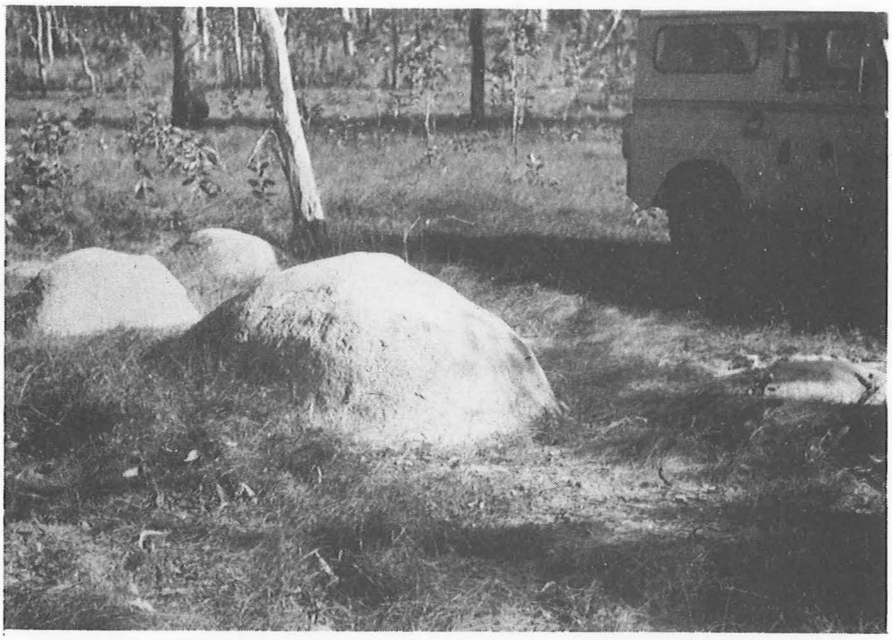


Plate i. Homogeneous granitoid diatexite (Plz_1) forming typical low boulder exposures on lightly wooded sandy plains; 11°57'S, 133°31'E, Junction Bay Sheet area. (GA/7631).

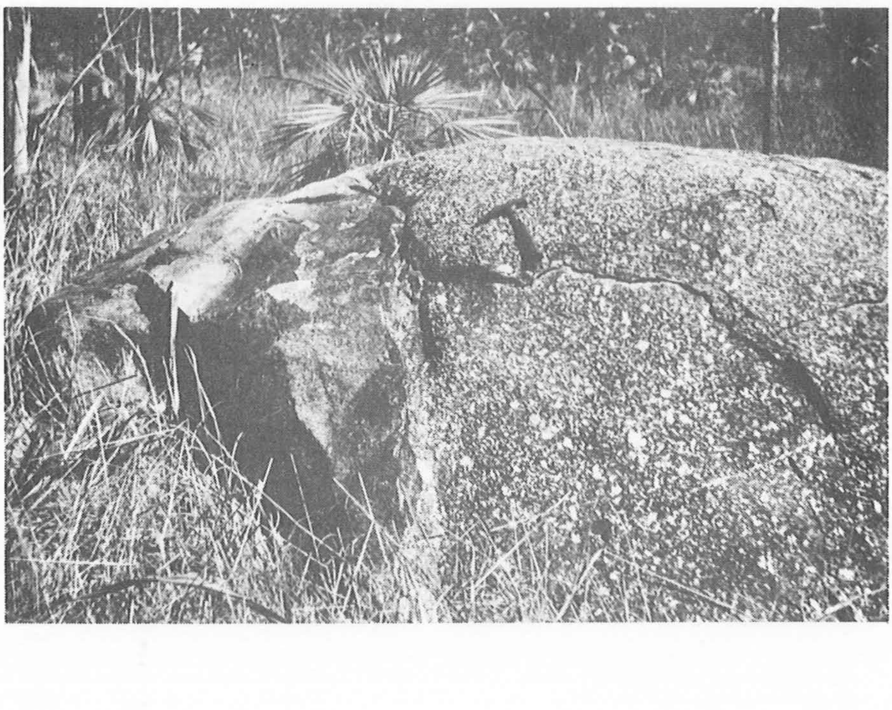


Plate ii. Porphyroblastic diatexite (Plz_1) with porphyroblasts <5 cm; containing basic xenolith. 17 km north of Nimbuwah Rock, Oenpelli Sheet area. (GA/7628).

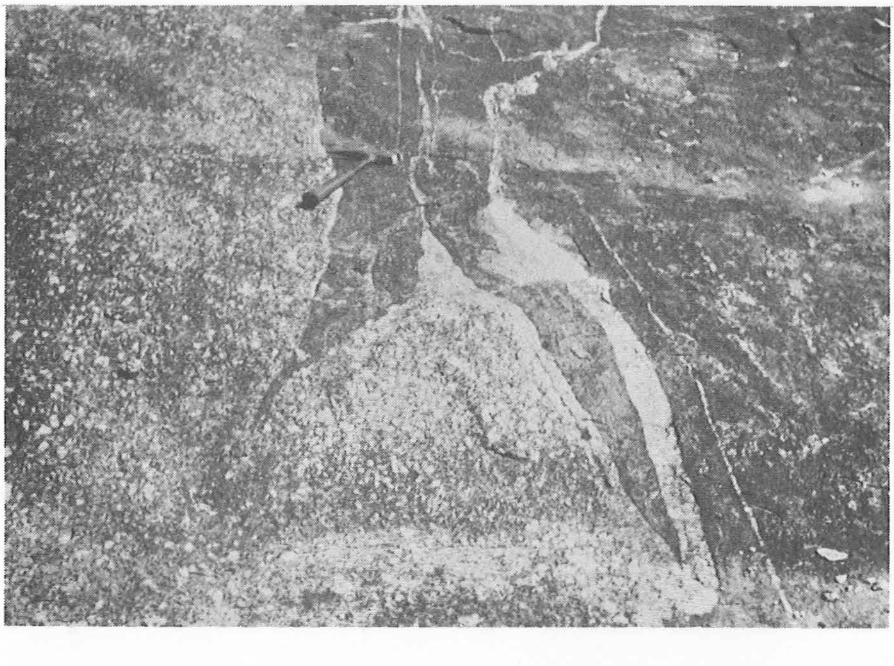
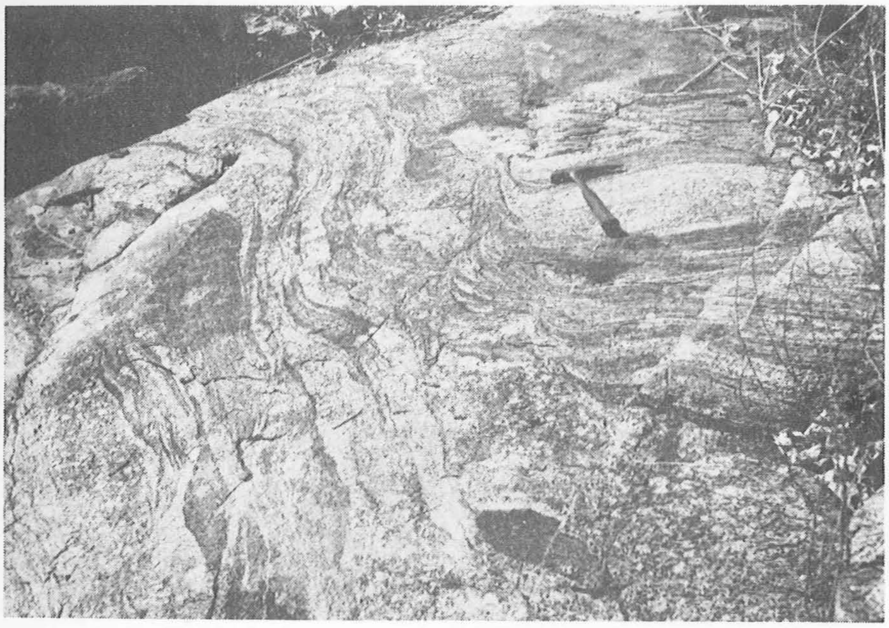
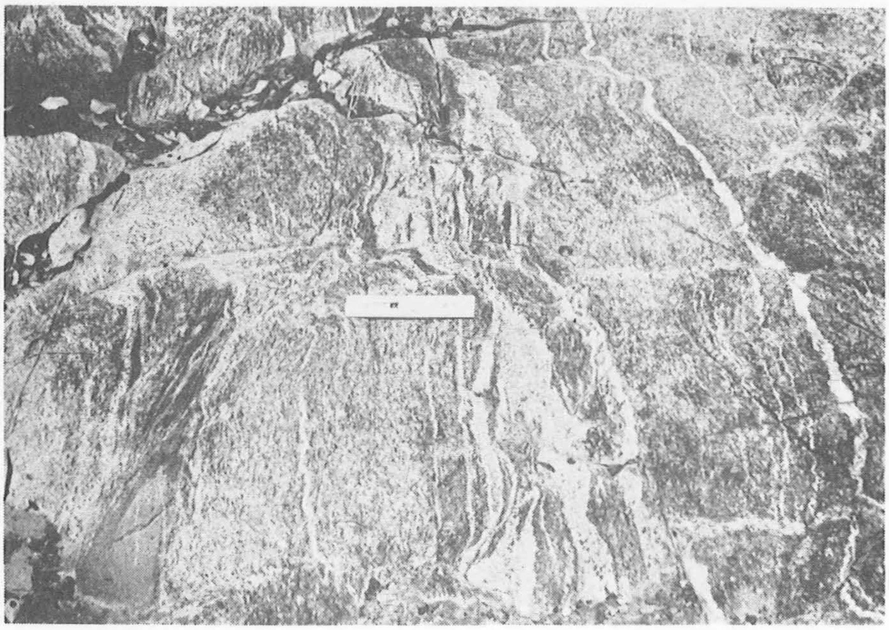


Plate iii. Porphyroblastic diatexite of the Granitoid Core (left) invading and assimilating banded metatexite of the Migmatite Zone (right). Eastern end of old airstrip, 2.5 km south of Maningkorrirr, Goomadeer Sheet area. (GA/7617).



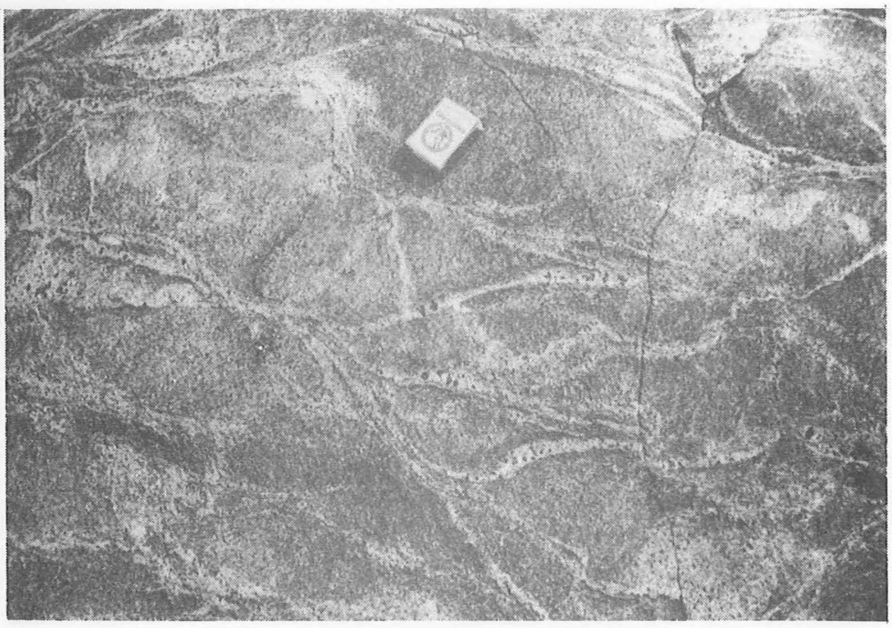
(a)



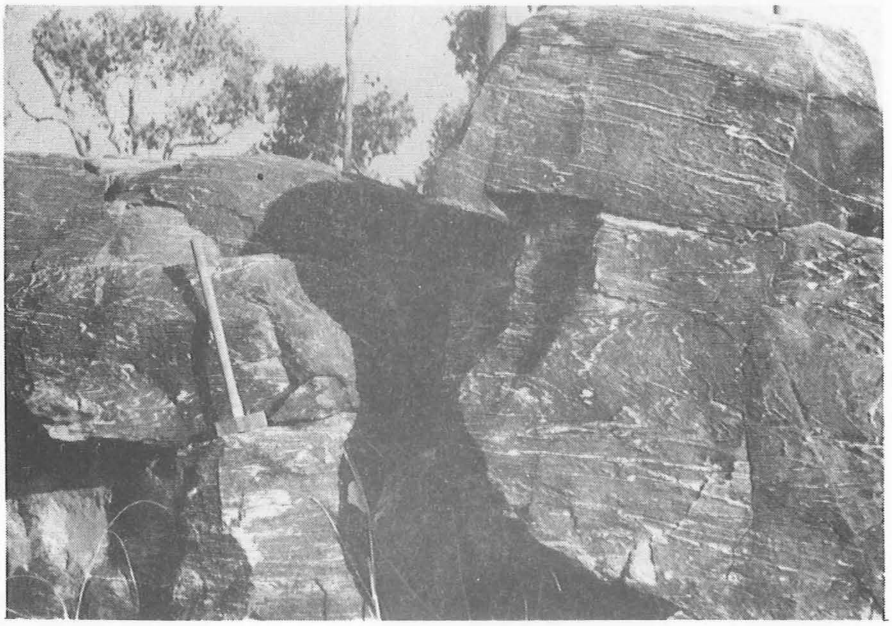
(b)

Plate iv. Migmatite fabrics (a) Schlieren migmatite; 12°11'S, 133°35'E, Goomadeer Sheet area. (GA/7630)

(b) Stromatic migmatite; 150 m south of Cretaceous mesa; 11°47'S, 133°11'E, Wellington Range Sheet area (GA/7618).



(a)



(b)

Plate v. Migmatite fabrics (a) Diktyonitic migmatite; hornblende forms blebs in leucosome bands (stictolithic). Bank of western King River, Wellington Range Sheet area 11°54'S, 133°22'E, (GA/7633)

(b) Ptygmatic migmatite; 12°17'S, 133°36'E, Goomadeer Sheet area (GA/7652)

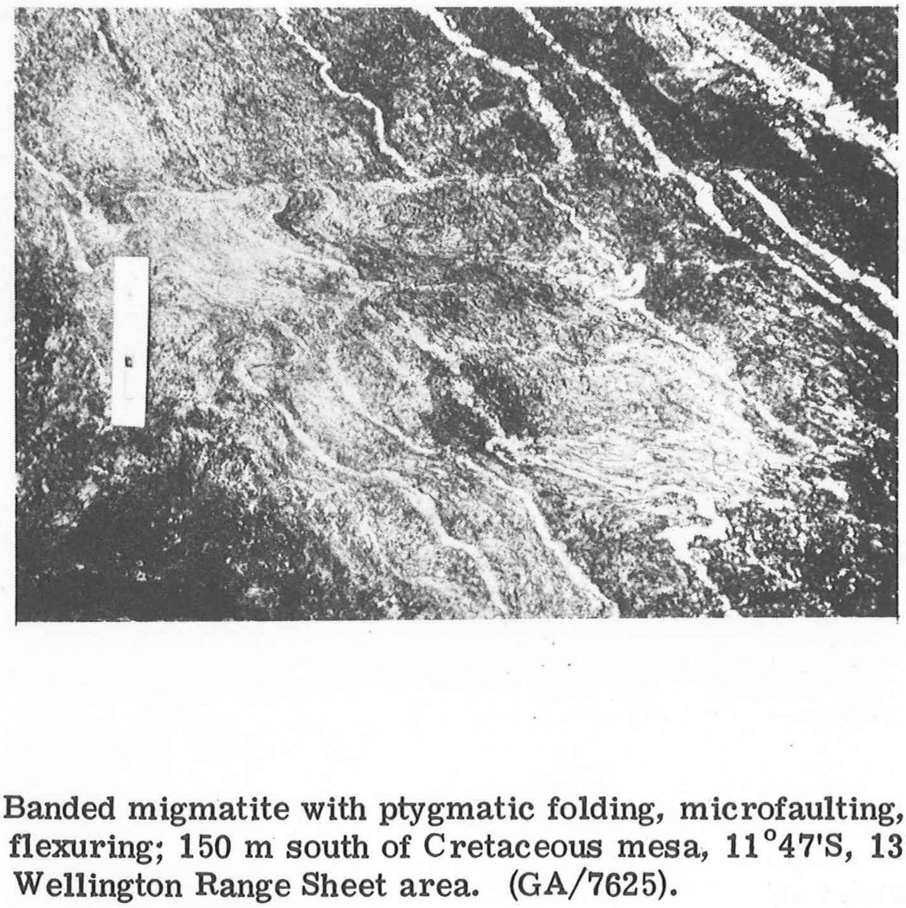


Plate vi. Banded migmatite with ptygmatic folding, microfaulting, and flexuring; 150 m south of Cretaceous mesa, 11°47'S, 133°11'E, Wellington Range Sheet area. (GA/7625).

the porphyroblastic diatexite of the Granitoid Core invaded (by ingestion rather than by displacement) rocks of the Migmatite Zone (Text-Plate iii). Invasion by the porphyroblastic diatexite was initially along the foliation, but, as assimilation progressed, cross-cutting relations developed. Xenoliths several metres within the invading rock retain parallelism with the parent rock body, and suggest an in-situ passive invasion (i.e., assimilation) rather than an active displacement.

Most of the classic structures described by Mehnert (1968, Chapter 2, pp. 7-40) have been observed within the Migmatite Zone of the Nimbuwah Complex. The most common structures are schlieren, stromatic, folded, nebulitic, ophthalmic, diktyonitic, and ptygmatic. Agmatic structures were observed at only a few localities, and the term 'banded' is used to describe migmatites with linear compositional banding. A variety of fabrics are shown in Text-Plates iv-vi.

Augen gneiss (ophthalmic migmatite) is a distinct subunit of Plz_2; it is largely confined to the outer margin of the zone. It represents an intermediate stage of metamorphic differentiation which is gradational between the rocks of the Lit-par-lit Gneiss Zone (Plz_3) and the other migmatites of Plz_2. The augen are crystalline aggregates of the leucocratic elements of the rock (leucosome), and represent a more advanced stage of migmatization than the lit-par-lit gneiss. The augen developed within an earlier fabric by crystal growth, pushing aside the adjoining minerals (i.e., blastesis).

The mineralogy of the Migmatite Zone is similar to that of the Granitoid Core; it consists of quartz, plagioclase, and biotite, with some hornblende, and clinopyroxene. Accessory minerals are magnetite, muscovite, apatite, tourmaline, sphene, and zircon. Biotite is commonly altered to chlorite, plagioclase to chlorite and sericite, and potash feldspar to sericite.

Lit-par-lit Gneiss Zone (Plz_3)

The boundary between the Migmatite Zone and the Lit-par-lit Gneiss Zone is poorly exposed. The main modes of outcrop are weathered rock in creek banks and beneath laterite scarps; exfoliated platforms; isolated hills, a few of which are capped by Kombolgie Formation sandstone; and rubbly exposures adjacent to quartz breccia reefs.

This zone is characterized by the development of subparallel leucocratic layers which represent the start of metamorphic differentiation of the parent rock into leucosome and palaeosome to form migmatite. The leucosome consists almost entirely of quartz and feldspar, and the palaeosome consists of biotite with some feldspar and quartz and minor garnet and opaque minerals. Finely banded biotite gneiss represents metamorphic differentiation on a microscopic scale, whereas lit-par-lit gneiss is formed by differentiation on a macroscopic scale. The incipient development of quartz-feldspar augen in feldspathic schist and banded biotite gneiss reflects a more advanced stage of metamorphic differentiation.

The major rock types in this zone are lit-par-lit gneiss and schist, biotite gneiss, muscovite-biotite gneiss, banded biotite gneiss, muscovite leucogneiss, biotite leucogneiss, and biotite hornblende gneiss. Other rock types are feldspathic mica schist, quartz-biotite schist, mica quartzite, feldspathic quartzite, amphibolite, garnet quartzite, and rare augen gneiss* and granitoid rocks.

Essential minerals in the gneisses are quartz, potash feldspar (generally microcline), plagioclase, and biotite. Plagioclase and potash feldspar are equally abundant in the gneiss, although their proportions in individual rock types are not constant. Plagioclase composition ranges between albite and andesine, and is relatively resistant to alteration, generally being only partly replaced by sericite. The potash feldspar is mostly sericitized, and may be completely replaced.

Biotite is the most common mafic mineral; however, hornblende is increasingly evident towards the inner margin of the zone, and in some rocks is the predominant mafic mineral. Muscovite, where present, is intimately associated with biotite as interlocking flakes, and rarely exceeds biotite in abundance. Pink garnet porphyroblasts, which are colourless in thin section, are a common minor accessory (usually 1%). Other accessory minerals are apatite, sphene, iron oxides, and zircon.

Where the gneisses are hornfelsed by the 'Oenpelli Dolerite', the feldspars are completely altered to chlorite and sericite, and biotite is replaced by chlorite. Relict gneissic texture is retained in the hornfelsed rocks.

The schists of the Lit-par-lit Gneiss Zone are mineralogically similar to the gneisses, apart from the predominance of biotite (and, in places, muscovite) over quartz and feldspar. Porphyroblastic garnet is the most common accessory mineral.

---

* Augen gneiss within this zone is deformational in origin (i.e., the augen are porphyroclasts) and is distinct from augen gneiss of Plz$_2$, which is a product of migmatization (i.e., augen are porphyroblasts)

Amphibolites constitute only a minor part of the Complex and they are mostly confined to the Lit-par-lit Gneiss Zone. Outcrop is restricted to foliated in-situ boulders, low platforms, and rock bars in creek channels. The best exposure is found beneath the Kombolgie escarpment 14 km east of Oenpelli Mission, where the amphibolite crops out as a band 10 m thick within a sequence of feldspathic schist and banded biotite gneiss for a distance of 1 km.

Many of the amphibolites display a granuloblastic texture; some, however, are strongly altered to radiating fibrous aggregates of actinolite, tremolite, and chlorite. A few amphibolites have relict ophitic texture, indicating that at least some of these basic amphibolites were pre-migmatization dolerites.

Euhedral actinolitic hornblende and plagioclase are essential minerals of the granuloblastic amphibolite. Accessory minerals are subhedral sphene, magnetite, and quartz granules, and fine prisms of apatite. Orthopyroxene (composition about En_{90}) and garnet porphyroblasts have been found in a few of these rocks, and may be relicts of earlier higher-grade metamorphism.

Steeply dipping quartzite forms discontinuous strike ridges and hills within the Lit-par-lit Gneiss Zone. The ridges are composed of isoclinally folded massive quartzite, micaceous and feldspathic quartzite, and rare garnet-bearing quartzite interlayered with quartz mica schist. The schist is readily weathered, and typically does not crop out. Rare pegmatite and quartz-tourmaline veins intrude the quartzite.

Transitional Zone (Plz_4)

The boundary between the Fisher Creek Siltstone and the Nimbuwah Complex is defined by the appearance of metamorphic feldspar, i.e. the development of leucosome; however, a series of transitional rock types lies between this boundary and rocks which are characteristic of the Lit-par-lit Gneiss Zone, in which bands of leucosome are commonly developed.

These transitional rock types are quartz-feldspar-biotite schist, garnet-quartz-feldspar-biotite schist, quartz-mica schist, quartz-chlorite schist, leucogneiss, banded biotite gneiss, feldspathic quartzite, and micaceous quartzite; pegmatoid leucosome is rarely developed. Metamorphic index minerals have not been found in the rocks of the Transitional Zone, but a proportional increase of gneissic textures reflects a subtle increase in metamorphic grade towards the Lit-par-lit Gneiss Zone.

A disturbed aeromagnetic pattern covering the area north of Oenpelli Mission is considered to indicate the presence of 'Oenpelli Dolerite' at depth

(Horsfall & Wilkes, in prep.). Extensive chloritization of the exposed rocks of that area - mostly Transitional Zone rock types - is an alteration effect, probably associated with the intrusion of the dolerite.

'NABARLEK GRANITE' (Pgn)*

Several low hills about 7 km east of Nabarlek (Map Plate 12) are composed of extensively altered granite. Isoclinally folded schist of the Lit-par-lit Gneiss Zone is adjacent to the southern flank of the granite; the contact is obscured by a zone of hematite-chlorite alteration. Kombolgie Formation sandstone overlies the granite to the north.

The granite is a pink coarse-grained biotite-rich type cut by narrow aplite dykes altered to sericite and quartz and rare associated pegmatites. Numerous quartz breccia zones, trending roughly north, are a characteristic feature of this unit, and are easily recognized on aerial photographs. The granite is anomalously radioactive, having a surface radioactivity of about 250 cps 8x background over the surrounding Nimbuwah Complex.+

Contact relationships between the granite and country rocks have not been seen in the field, but the granite is thought to intrude the surrounding gneiss and schist of the Nimbuwah Complex. The granite is probably an equivalent of the core of the Nimbuwah Complex (Plz_1), formed by anatexis and then mobilized, and intruded into higher levels of the migmatite complex. It has been intersected by diamond drilling at Nabarlek at a depth of about 400 m. The granite may extend south to the eastern end of the Myra Falls Inlier, where granitic rocks were mapped by Walpole et al. (1968).

BASIC AND INTERMEDIATE INTRUSIVE ROCKS

Needham & Smart (1972) considered the basic intrusive rocks of the Cahill and East Alligator Sheet areas to be predeformational, and the phonolite dykes to be post deformational. Within the predeformational intrusives (Pdo_1) two distinct mineralogical groups were described: one derived from a tholeiitic parent magma, the other from an alkali basalt parent.

---

* Name reserved but not yet approved by Stratigraphic Nomenclature Subcommittee.

\+ Subsequent work has shown that the Tin Camp Granite, exposed 20 km south of the Nabarlek Granite, and considered to be comagmatic, averages 60 ppm Th and 11 ppmU, compared with 8 ppmTh, and less than 4 ppm U for the Nimbuwah Complex (Wilkes, 1975).

We now believe that the alkali basalt intrusives are postdeformational, and have named them the 'Oenpelli Dolerite'* (see Appendix 1). The differentiated intrusion in the Howship 1:100 000 Sheet area described by Needham & Smart (1972 p. 28) is considered to be part of the 'Oenpelli Dolerite'. In this outcrop separate phases of porphyritic olivine dolerite, ophitic dolerite, ophitic gabbro, granophyric dolerite, syenite, and granophyre were found but inadequate exposure made it impossible to elucidate the boundary relationships of these phases. The slightly sodic nature of these intermediate and acidic differentiates indicates possible alkali basalt parentage, but no geochemical data is yet available. Other criteria indicating a similar parentage are:

(i) the presence of Mg-rich olivine phenocrysts in the porphyritic olivine dolerite phase (i.e., Fo_{70} determined optically).

(ii) the absence of quartz and presence of olivine granules in the groundmass of early phases of the intrusion.

(iii) the presence of biotite as phenocrysts and in the groundmass of the doleritic phases.

Similar observations have been made for the 'Oenpelli Dolerite' in the Oenpelli area, and also in the Jim Jim area (Needham, Smart & Watchman, 1975).

The tholeiitic intrusives are predeformational and represent a northern continuation of the Zamu Complex (Stewart, 1959). We now realize that the degree of metamorphism of the tholeiitic intrusives increases northwards. Amphibolites in the Nimbuwah Complex are probably metamorphosed Zamu Complex dolerites, their igneous textures having been obliterated by the high grade of regional metamorphism (at least staurolite grade).

A group of phonolite dykes, mineralogically similar to the phonolites of the Cahill Sheet area described by Needham & Smart (1972), crop out in the Goomadeer Sheet area (Plate 9) and are likewise post deformational. They have been named the 'Maningkorrirr Phonolite'* (see Appendix 1).

'Oenpelli Dolerite' (Ƀdo)*

Aeromagnetic data, igneous lamination, and jointing suggest that the 'Oenpelli Dolerite' forms a series of shallow ellipsoidal basins or lopoliths, which are locally displaced by faulting. The thickness of the dolerite is not constant, and could reflect thickening towards the centre of lopolith-type bodies. Drilling has indicated a thickness of 250 m at Nabarlek, and 130 m at

---

* Name approved by Stratigraphic Nomenclature Subcommittee, but not yet published.

Black Rock. The 'Oenpelli Dolerite' crops out as discontinuous in-situ boulders from the edge of the Arnhem Land Plateau south of Oenpelli Mission to Aurari Bay in the north, and from the eastern tributaries of the King River to near the East Alligator River. It extends south of Jim Jim Falls (Needham et al., 1973, 1975), and the narrow altered dolerite dykes intersected at Ranger 1 may represent its most westerly extent. Where the dolerite is poorly exposed its subsurface presence is indicated by distinctive red-brown soil, characteristic vegetation with a dark photo-pattern, or black humic soil flats. It is a symmetrically differentiated basic intrusion with only minor intermediate and acidic phases (Fig. 4). Textural differences between the phases allow them to be distinguished in the field. Mineralogical differences between the major phases are more subtle, although the pink potash feldspar of the syenite and granophyre is quite distinctive.

The following phases have been recognized:

Chilled margin. Few outcrops of the chilled margin were seen. It is 2-4 cm wide, and is composed of black fine grained porphyritic olivine basalt with small, partly assimilated xenoliths of schist. Contacts with porphyritic olivine dolerite are both transitional and sharp.

Porphyritic olivine dolerite. This phase grades from a strongly porphyritic type with a fine basalt-textured groundmass near the chilled margin to a type with fewer phenocrysts and a coarse groundmass which is transitional into ophitic dolerite at its inner margin. Typically this phase is represented by a fine-grained grey rock with large green phenocrysts of plagioclase up to 5 cm long, some forming glomeroporphyritic aggregates. Other less prominent phenocrysts include greenish yellow glassy olivine, prisms of augite, titanomagnetite, and rare biotite flakes. In the groundmass augite generally bears a subophitic to ophitic relationship to plagioclase laths, but it may poikilitically enclose them. The groundmass consists essentially of plagioclase laths, augite, olivine granules, and titanomagnetite. All these minerals contain inclusions of apatite as euhedral prisms.

Gabbroic pegmatite. This very coarse-grained phase is a relatively minor constituent of the intrusion. It occurs as discrete pods and veins near the chilled margin of the intrusion. The pegmatite consists of ophitic intergrowths of plagioclase, clinopyroxene (augite) and some opaque minerals, fractured olivine crystals, and minor apatite.

Ophitic dolerite (to ophitic gabbro). The ophitic phase forms the bulk of the intrusion. It is quite uniform in appearance, showing differences only in grainsize and degree of alteration. The ophitic dolerite is a medium to

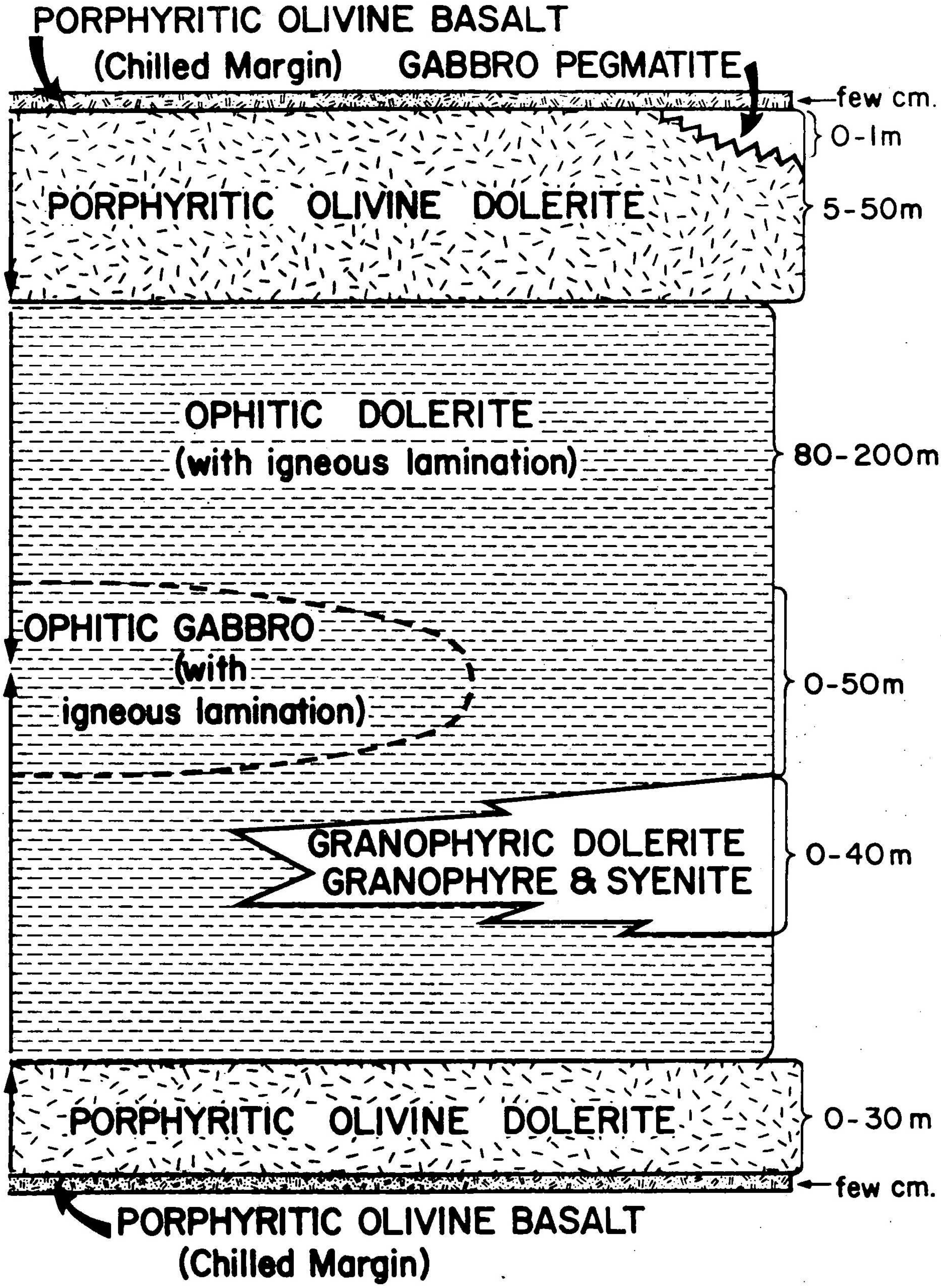


Fig. 4 Schematic diagram showing the internal structure of the 'Oenpelli Dolerite'. Arrows indicate direction of increase in grainsize of groundmass.

To accompany Record 1975/39

D53/A5/17

coarse-grained green and grey speckled rock which generally contains accessory amounts of disseminated pyrite and chalcopyrite. It is typically massive; jointing is parallel to the margins of the intrusion and gives the rock a layered appearance. A weak igneous lamination, which is more obvious in outcrop than on a microscopic scale, appears to be due to preferred alignment of the feldspars.

The porphyritic nature of the ophitic dolerite is seen only in thin section. Most of the phenocrysts, which comprise less than 5 percent of the rock, are resorbed, oscillatorily zoned, multiply twinned plagioclase laths, and augite crystals with multiple twinning. Relict olivine crystals are rare; generally they are completely pseudomorphed by fibrous to amorphous green serpentine. The groundmass is composed essentially of ophitic intergrowths of clinopyroxene and plagioclase with skeletal titanomagnetite and some interstitial late-stage quartz, albite, and potash feldspar. Apatite is a common accessory. Chlorite, uralite, epidote, and calcite are alteration products. In strongly altered rocks plagioclase is completely replaced by saussurite, and clinopyroxene is uralitized.

The groundmass grainsize increases, and the texture may become gabbroic toward the centre of the dolerite. The mineralogy of the ophitic gabbro phase is similar to that of the ophitic dolerite.

Granophyric Dolerite: This phase forms narrow discontinuous lenses in the ophitic dolerite, and in places is differentiated further into syenite and granophyre. It is typically a medium to coarse pink and green speckled rock containing some disseminated sulphides, and is generally strongly deuterically altered.

The granophyric dolerite is characterized by the extensive development of graphic intergrowths of quartz and potash feldspar which typically accounts for more than 20 percent of the rock. Augite and pigeonite have ophitic relationships with plagioclase laths. Commonly only relict ophitic texture is seen, as the clinopyroxenes are altered to actinolitic hornblende or uralite, and plagioclase is sericitized or saussuritized. Other minerals include skeletal titanomagnetite, chlorite, and rare biotite.

Syenite and granophyre: The more differentiated syenite and granophyre phases of the intrusion are far less commonly developed, and their contacts with other phases are not exposed. The syenite is a medium to coarse, pinkish to brick-red rock with scattered dark green radiating aggregates of prismatic amphibole. The granophyre is of similar appearance but contains only minor small patches of dark amphibole and is generally medium-grained. Brick-red varieties are heavily ferruginized.

The syenite and granophyre are mineralogically similar, and consist essentially of potash feldspar, sodic plagioclase, quartz, amphibole, and minor opaque iron oxides. Potash feldspar mostly forms strongly altered Carlsbad-twinned subhedral laths which are invariably clouded with minute inclusions of red-brown iron oxide. Less altered and clouded crystals are seen to be microperthite. Some feldspar laths display polysynthetic twinning. These sodic plagioclase crystals are rimmed irregularly by potash feldspar. Quartz occurs as clear anhedral grains, and as interstitial eutectic intergrowths with alkali feldspar. In the granophyre these micrographic intergrowths form the bulk of the rock. The chief mafic mineral in the syenite is a pleochroic, blue-green to brown amphibole, probably a slightly sodic hornblende. It commonly forms ragged prisms which are associated with minor clinopyroxene, black iron oxides, acicular apatite prisms, and radiating fibrous aggregates of chlorite in mafic clots. Clinopyroxene is generally altered along cleavages, and is rimmed by sodic hornblende. Black iron oxides occur as skeletal grains, irregular interstitial grains, acicular prisms, and inclusions in the amphibole. Apatite forms at least 1 percent of the syenite in places. Epidote, chlorite, sericite, and calcite are common alteration minerals.

The amphibole in the granophyre has stronger pleochroism, and is probably more sodic than that in the syenite. Another factor which points to the more differentiated nature of the granophyre is the abundance of eutectic intergrowths.

Where the 'Openpelli Dolerite' intrudes the Fisher Creek Siltstone and the outer zones of the Nimbuwah Complex (Plz_3 and Plz_4) it displays sharp contacts. The metamorphic aureole, in which only the albite-epidote hornfels facies appears to have been reached, is not, however, everywhere recognized, and probably has a range of widths. Contact effects are best seen near a prominent hill, known locally as Hill 335, 14 km north of Oenpelli Mission. The true width of the contact aureole may be less than 50 m, but as the dolerite is relatively flat-lying, and underlies much of the area at shallow depth, hornfelsed schist and gneiss crop out over a large area. In the aureole mafic minerals are altered to chlorite, and feldspars to sericite + chlorite + epidote. Biotite gneiss is altered to quartz-sericite-chlorite rock. Recrystallization in these rocks is rarely complete, and they are therefore recognizable as hornfelsed gneiss by their relict texture. Generally, however, hornfelses show no relict textures indicative of high-grade contact metamorphism and appear to have merely reached albite-epidote hornfels facies.

The absence of pyroxene hornfels or even hornblende hornfels facies rocks immediately adjacent to the dyke is anomalous for a basic intrusive

intrusive of this thickness (i.e., 100-250 m). Experimental work by Winkler (1965, p. 63) suggests that if a gabbro 200 metres thick was intruded at a shallow depth (1-2 km), then a pyroxene hornfels zone should extend at least 40 m from the contact, and a hornblende hornfels zone a further 40 m. A possible explanation for the absence of high-grade contact metamorphism is that very high water pressure prevailed in the country rocks during the period of intrusion and cooling. Hence hydrous minerals such as chlorite may have been stable at much higher temperatures than normally expected. Where the dolerite intruded rocks of higher grade in the Nimbuwah Complex, contact relations with the gneissic and granitoid rock are completely different: there is no hornfelsing of the country rocks, but instead they have been partly assimilated by the dolerite magma. The degree of assimilation increases towards the core of the Complex. In the Granitoid Core of the Nimbuwah Complex the dolerite is probably represented by basic xenoliths indicating almost complete assimilation.

In places the upper margin of the dolerite is serpentinized. The serpentinite, which is strongly slickensided, is easily weathered to yellow-green clay. It crops out only in deep erosion gullies where it is exposed to depths rarely exceeding 2 m. The degree of marginal serpentinization of the dolerite suggests that some local thrusting accompanied its intrusion.

One exposure of chloritic slickensided serpentinite (12°08'S, 132°50'E) 16 km northwest of Ngara airstrip, (Map Plate 6) may represent serpentinized pyroxenite rather than serpentinized dolerite, although porphyritic dolerite crops out nearby. Magnesite nodules, talc schist, and pyroxenite have been identified near this locality. The serpentinite contains minor disseminated chalcopyrite and other sulphides which have not yet been examined microscopically. It is therefore possible that these rocks form part of a poorly exposed older ultramafic belt intruded at shallow depth by the 'Oenpelli Dolerite'.

'Wurugoij Dolerite' (Bdw)*

An isolated small plug-like dolerite body situated at 12°13'S, 133°47'E, and measuring about 50 m across, appears to intrude the surrounding Kombolgie Formation sandstone (Map Plate 10). The sandstone has been metamorphosed to a hard columnar-jointed pure quartzite adjacent to the dolerite.

The dolerite is similar in texture and mineralogy to the ophitic dolerite phase of the 'Oenpelli Dolerite'. It intrudes the lower sandstone unit of the Kombolgie Formation, below the Nungbalgarri Volcanic Member, and

* Name reserved, but not yet approved by Stratigraphic Nomenclature Subcommittee.

is possibly a feeder to those basic volcanics. Alternatively, it may be related to dolerites of the Carpentarian Province which intrude Adelaidean strata in the Roper and Bulman districts (Roberts & Plumb, 1964; Dunn, 1963). The name 'Wurugoij Dolerite' is proposed for the dolerite.

'Maningkorrirr Phonolite'*

An area of about 4 km^2, 3 km east of the headwaters of Jungle Creek, is extensively intruded by straight parallel-sided steeply dipping phonolite dykes (Map Plate 9), which are typically dark grey-green, fine to medium and commonly porphyritic. The dykes are generally 30-50 cm wide, but may be up to 1 m, and up to 1 km long. Their preferred orientations are northeast and northwest. They display a diversity of textures ranging from fine-grained, to coarsely porphyritic (Text-Plate vii). The centre of the widest and longest dyke is composed of up to 50 percent of sanidine phenocrysts which form a wedge-shaped raft possibly reflecting the direction of intrusion of the dyke. The hemicylindrical aligngmentment of phenocrysts across the same dyke also indicates the direction of pressures within the dyke during intrusion. In this case the phenocrysts are arranged in arc-like accumulations across the total width of the dyke, and are aligned perpendicular to the direction of intrusion.

These phonolites are similar mineralogically to those described by Needham & Smart (1972) near Mudginberri homestead, for which the name 'Mudginberri Phonolite'* has been proposed, but occasionally contain xenoliths of granitoid migmatite. The partly assimilated xenoliths indicate hybridization of incorporated material at depth during or before intrusion. The margins of the dykes are sharp, and show no evidence of assimilation or contact effects on a macroscopic scale.

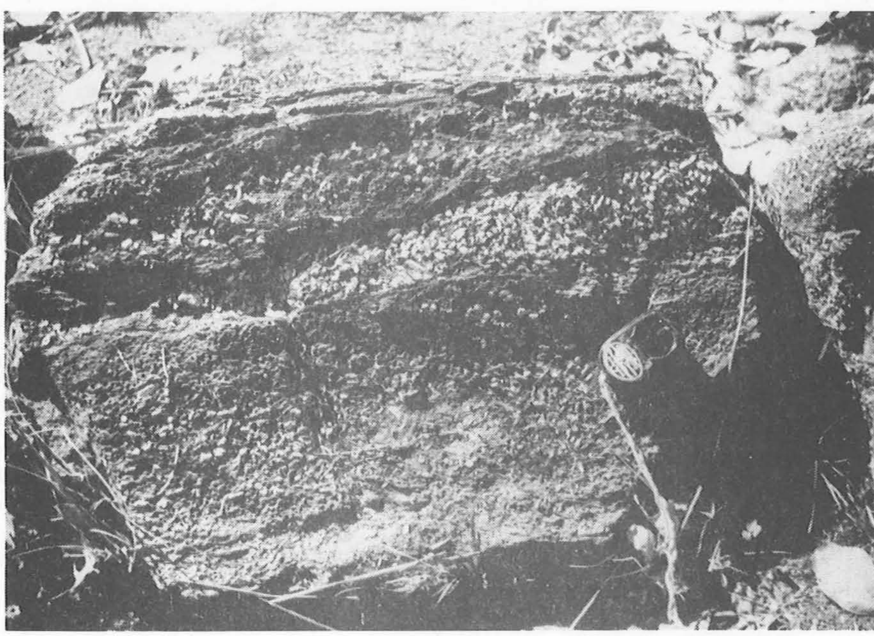
The 'Maningkorrirr Phonolite' is unmetamorphosed, but shows various degrees of alteration. The phenocrysts are mostly euhedral anorthoclase, tabloid sanidine, zoned euhedral aegirine-augite, and rare biotite and opaque minerals. Some of the pyroxenes are rimmed by a pleochroic green amphibole which also occurs in the groundmass. The fine-grained groundmass is generally strongly altered and consists of sanidine, anorthoclase, aegirine-augite, biotite, titanomagnetite, and accessory sphene. No nepheline has been identified in these rocks to date. The aegirine-augite is partly altered to a fibrous blue amphibole.

A trachyte dyke with alkali affinity is exposed 10 km east of Nimbuwah Rock, and may be related to the phonolites. It is, however, quartz-saturated and the clinopyroxene is not as sodic as that in the phonolites.

---

* Name approved by Stratigraphic Nomenclature Subcommittee, but not yet published.

(a)
GA/7626



(b)
GA/7621

Plate vii

(a) Phonolite dyke cuts across extensive pavement exposure of Nimbuwah Complex porphyroblastic diatexite and schlieren migmatite; a directional structure within the phonolite parallels the sides of the dyke. 12°10'S, 133°25'E.

(b) Wedge-shaped raft of phenocrysts in centre of porphyritic phonolite dyke. Block is a complete cross-section of the dyke, 60 cm wide. 100 m south of Plate vii(a).

KOMBOLGIE FORMATION (Phk_1, Phn, Phk_2)

The Carpentarian Kombolgie Formation forms the Arnhem Land Plateau, whose edge is marked by a sheer scarp face up to 200 m high in the west of the survey area, and is the most prominent relief feature. Most observations of the formation were made at the base of the scarp, except in the east of the survey area, where the plateau surface lies at about the general level of the Coastal Plains.

In the Goomadeer 1:100 000 Sheet area lower and upper sandstone units (Phk_1 and Phk_2), separated by a basalt flow (the Nungbalgarri Volcanic Member, Phn,), are exposed. The sandstone is composed mainly of medium to coarse (0.25 - 1.0 mm) moderately well sorted subrounded to subangular quartz grains; matrices range from amorphous and fibrous clay minerals to opaque iron oxides. Friable varieties are essentially devoid of a matrix, whereas quartzitic varieties are composed of either interlocking grains or are cemented by fine quartz.

In addition to the typical sandstone, the formation includes fine ferruginous siltstone and conglomerate containing subrounded to well rounded quartz cobbles up to 20 cm in diameter. Conglomerate beds range from 20 cm to over 30 cm thick, and are more common below the volcanic member. Basal conglomerate, developed directly above the underlying Lower Proterozoic rocks, generally consists of up to 80 percent of subangular quartz and quartzite pebbles (commonly feldspathic), up to 10 percent of shards of Lower Proterozoic schist, and up to 2 percent of highly angular fragments of vein quartz. The distribution of the basal conglomerate is sporadic, and is controlled by relief of the pre-Kombolgie surface.

The upper sandstone unit is generally more homogeneous than the lower one. Both the upper and lower sandstone are characteristically buff to yellow in colour on weathered surfaces, and extensively jointed.

The sandstone throughout the formation is commonly cross-bedded and ripple-marked. The cross-bedding is mostly medium scale (5 cm - 2 cm) of the 'alpha' type, described by Allen (1963), which suggests of a shallow freshwater origin for the sediments. The number of measurements made of directional sedimentary structures in the survey area are insufficient to determine the direction of provenance. Ripple marks are commonest in thin-bedded flaggy parts of the sandstone members. Each bed invariably displays a prominent set of ripples which bears little if any directional relationship to those of adjacent beds. During the earlier stages of deposition, source areas may have been different for the various sub-basins delineated by ridges of Oenpelli Dolerite.

The volcanic member consists of amygdaloidal to massive dark grey-black basalt. Those specimens collected were all highly altered and sericitized, composed of labradorite laths, skeletal augite and magnetite, chlorite, and minor quartz and amorphous silica (agate) rimming amygdales. The coarser varieties have ophitic textures. Minor lenses of sandstone and tuffaceous siltstone were mapped within the volcanic member. The tuffaceous siltstone contains fine bands of brown and mauve ferruginous chert interlayered with vermicular-textured glassy material; magnetite grains are distributed predominantly marginally to the layers of glassy material; micro-folds and dislocations were evident in the chert bands. Because the tuffaceous siltstone is readily weathered at the surface, specimens for examination could only be collected from shallow exploration costeans.

BUCKINGHAM BAY SANDSTONE (Cwb)

This formation is the basal unit of the Cambrian Wessel Group.* According to Rix (1965), it consists mainly of alternating medium-grained massive purple quartz greywacke, quartz sandstone containing Scolithus, and flaggy fine-grained micaceous quartz greywacke. In the Junction Bay and Goomadeer Sheet areas, however (Map Plates 5 and 10), white medium-grained quartz sandstone predominates. Sphericity ranges from predominantly sub-rounded to subangular; sorting is bimodal, and the rock is composed of about 98 percent quartz, sometimes strained or etched, and up to 2 percent quartzite. Packing is tight, and no matrix was discernable in those rocks examined in thin section. In outcrop, however, the rocks often have a white clayey appearance which is due to the presence of a kaolinitic matrix, in contrast to the porous buff-yellow appearance of Kombolgie Formation sandstones.

RAIWALLA SHALE

Although this unit forms the predominant part of the Wessel Group, it does not crop out in the area mapped. Rix (1965) described the unit as predominantly fissile grey, green, and purple shales.

MARCHINBAR SANDSTONE (Cwm)

Isolated rock ledges of possible Marchinbar Sandstone were photo-interpreted along the coast of Junction Bay. None was visited during the field season; Rix (1965) described the unit as consisting of flaggy quartz sandstone and feldspathic sandstone.

---

* Middle Cambrian trilobites in rock slabs probably derived from the Elcho Island Formation (topmost Wessel Group) have recently been described by Plumb et al. (in prep.). Previously the group was thought to be Adelaidean, based on age dating of glauconite by McDougall et al, 1965.

BATHURST ISLAND FORMATION

Mesozoic sediments of the Oenpelli region have been assigned to the Lower to Upper Cretaceous Bathurst Island Formation by Hughes & Senior (1973, 1974).

Flat-lying Lower Cretaceous (Aptian) strata cover most of the central and northern parts of the region. They are usually exposed in small scarps up to 4 m high at the margins of the outcrop areas, as they are mostly overlain by Cainozoic sand and laterite (Text-Plate viii). The Mesozoic is no more than 10 m thick in the Goomadeer Sheet area (Map Plates 9 and 10), but thickens north and west. Over 40 m has been intersected by drilling in the East Alligator NE Sheet area (Map Plate 6). It is composed predominantly of medium to coarse-grained clean quartz sandstone and minor siltstone; the sandstone contains subrounded to rounded quartz grains, minor quartzite grains, and very minor muscovite in a matrix composed of very fine-grained and cryptocrystalline silica. The framework grains occasionally have a secondary overgrowth of silica around their margins.

The sediments were named the Marligur Member (Kla) by Hughes & Senior (1973), who regard them as marginal marine to beach facies. The beds contain Bacculites sp., gastropods, and bivalves; an internal cast of an ammonite was collected, but was accidently destroyed before identification was made. The best fossil locality is the hill on the east of Jungle Creek, at 11°59'S, 133°40'E.

The Marligur Member appears to become slightly more silty northwards, and, northwest of Wellington Range, is succeeded by the deltaic Upper Cretaceous (Cenomanian) Moonkinu Member (Kum), which is fine to very fine sublabile sandstone interbedded with grey mudstone.

Undifferentiated Lower Cretaceous freshwater unfossiliferous siltstone, sandy siltstone, and sandstone on top of the Arnhem Land Plateau in the south of the Oenpelli region are probably equivalent to the Darwin Member of the Bathurst Island Formation (Hughes & Senior, 1974).

CAINOZOIC UNITS

Cainozoic sediments form a veneer over the Northern Plains, the Arafura Fall, and the Coastal and Estuarine Plains, and also form talus slopes and colluvial sand cover over the Arnhem Land Plateau.

The deposits have been divided into the following units: laterite, Late Tertiary sands, colluvial silt and sand, talus, and Quaternary continental and marine sediments.

Laterite (Czl)

Generally the profiles seen in the survey area are either detrital or are truncated remnants of the standard laterite profile described by Whitehouse (1940).

Of the laterite types described by Williams (1969) in the Adelaide River/Alligator River area, the following types have been recognized;

Detrital laterite is formed mainly from reworked material cemented in a ferruginous matrix. It generally forms blocks (up to 1 m) and pavements on low hills or breakaways over the Fisher Creek Siltstone and Nimbuwah Complex.

Pisolitic laterite is the upper part of the standard laterite profile, and consists predominantly of cemented ovoid ironstone pisoliths, between 0.25 and 1 cm in diameter, which are commonly case-hardened or varnished. It occurs as blocks or pavements, mostly exposed in the stable regime at the margins of the depositional environment of the Estuarine Plains and Tidal Flats. Isolated detrital deposits of pisolitic laterite occur in places within depositional drainage systems. It can also be detrital.

Mottled-zone laterite is the middle part of the standard laterite profile, and consists of deeply weathered bedrock grading up into a ferruginous zone of generally pisolitic laterite, and down into a pallid zone. It commonly occurs over the Nimbuwah Complex and Fisher Creek Siltstone in the bottom of amphitheatres at the head of creeks, and is typically surrounded by a breakaway of pisolitic or detrital laterite.

Concretionary laterite is pedogenetic in origin and, unlike the laterites already described, is actively forming, rather than being in an erosional or stable environment. It is expressed as ferruginous mottling in poorly drained alluvial soils, or as ironstone nodules in situ in the soil profile.

Late Tertiary sand (Czs)

Coarse unconsolidated quartz sand forms the remnants of the Koolpinyah Surface, which covers much of the survey area; in places it is dissected. Where the sands have been almost completely removed, structures

Plate viii. Marligur Beds form low mesas and scarps over Nimbuwah Complex granitoid rocks; 12°04'S, 133°32'E, Goomadeer Sheet area. (GA 7620) within the underlying weathered rocks become apparent on aerial photographs.

The Late Tertiary sand is probably a fan deposit (Story et al., 1969) derived from Mesozoic sand, silt, and claystone, Kombolgie Formation sandstone, and Lower Proterozoic rocks. Clean, unconsolidated quartz sand, developed in situ on the Arnhem Land Plateau from Kombolgie Formation sandstone, has formed continuously in an erosional environment since the Early Tertiary.

At the margins of the Estuarine Plains and the Tidal Flats, erosion and redeposition of Czs have produced a narrow but distinct photogeological unit (Cza) which is characterized by a relatively steep slope of 5°; winnowing of the sands by erosion has resulted in the development of a sandy veneer on the slope. Because they are a direct product of erosion of unconsolidated sands and not part of the open drainage system, the clay and silt deposits found in isolated 'swallow holes' developed on the Koolpinyah Surface are also included in the Cza unit; their formation has probably been continuous since the Early Tertiary.

Colluvial silt and sand (Czw)

In the Wellington Range and Goomadeer Sheet areas, extensive areas of colluvial silt and sand, derived mostly from Cainozoic sand (Czs) and the underlying Marligur Member (Kua), are situated between the low Mesozoic scarp and the coastal deposits. The unit presents a unique mottled photo-pattern, probably reflecting its development over highly leached Mesozoic strata.

Talus material and rubble (Czt)

Talus slopes are commonly developed adjacent to the Arnhem Land Plateau where the base of the Kombolgie Formation is above ground level. In places the scree conceals the contact between the Kombolgie Formation and the underlying strata, but locally a bench is developed at the top of the talus slope, and the unconformity is exposed below an overhang of sandstone formed by preferential erosion of the Lower Proterozoic rocks. The talus is composed mostly of large blocks (up to 20 m) of Kombolgie Formation sandstone, but pebbles or shards of the underlying rocks are commonly present.

Laterite, quartz, quartzite, and dolerite rubble are widely scattered over the Northern Plains. The quartz and quartzite rubble is developed adjacent to strike ridges of Nimbuwah Complex schist, gneiss, and quartzite or other similar strata close to the surface.

Dolerite is a common constituent of rubble in almost every part of the area mapped. Notably it occurs adjacent to outcrops of quartz, quartzite, and the more massive varieties of gneiss on which 'grinding hollows' are seen. Aboriginals commonly used it for making artifacts; they transported the rock to suitable 'workshops' where they fashioned it into tools. Most of the dolerite rubble seen was assumed to have been transported by man; therefore only definite outcrops of basic intrusives have been shown on the maps.

Quaternary continental deposits

Deposition in a continental environment during the Quaternary is represented by a variety of alluvial types.

Alluvial silt, sand, and clay (Qa) occur in the courses and flood plains of active rivers. Large bodies of unconsolidated quartz sand (Qs) within the channels of major creeks and rivers, and outwash deposits (Qs) over the adjacent flood plains, consist mostly of material derived from the Kombolgie Formation or Late Tertiary sand, and were mostly deposited during floods. The sediments of abandoned river courses (Qas) consist mostly of silt and mud. The oxbow lakes developed before the late Pleistocene to Recent emergence are shallow depressions in the surface of the flood plain, into which the present drainage system is incised. Silty levee deposits (Qal) are developed along the courses of some of the larger rivers. Black humic soils and clays (Qf) are commonly developed in poorly drained depressions within drainage systems. Those adjacent to the Arnhem Land escarpment often display anomalous radioactivity but their limited depth (up to 3 m) and lateral extent preclude economic interest. However, they may be useful in indicating areas of mineral potential below the Kombolgie Formation.

Quaternary marine deposits

During the wet season (November to April) marine conditions strongly influence deposition in the major river courses for a considerable distance inland: brackish water extends 25 km inland in the Goomadeer River.

Coastal alluvial deposits (Qca) are comparatively well drained silt and clay deposits with sparse vegetation cover, such as sedge or samphire, and stand above the poorly drained black soil plains and mud pans (Qcp), which are also developed adjacent to, and within, estuarine channels. Salt pans are developed in areas bordered by Czs which are perenially waterlogged, and support paperbark and waterweed growth (e.g., the Arrla Bay swamps).

The <u>coastal sand ridges</u> (Qcr) are generally parallel to and within 2 km of the present coastline, or are adjacent and parallel to the edge of Czs. In the latter situation the strand lines developed at the beginning of coastal progradation during the Pleistocene (Christian & Stewart, 1953). The dunes are commonly composed of shelly sand, and support a woodland of non-eucalypts or semideciduous trees.

STRUCTURE

North and northeast strikes predominate in the Fisher Creek Siltstone throughout the East Alligator NE Sheet area and near Oenpelli Mission, but farther east the trendlines are increasingly complicated. Trendlines within the Lit-par-lit Gneiss Zone of the Nimbuwah Complex cannot be easily related to structures, as many groups of phototrends are commonly terminated or offset by photolineaments which are not exposed, and hence their relevance is unknown.

Leucosome bands developed in the Transitional and Lit-par-lit Gneiss Zones are parallel to the foliation in the metamorphosed Fisher Creek Siltstone; the foliation broadly coincides with bedding. It is possible that the banding in the Migmatite Zone also reflects bedding trends. We believe that the quartzite in the Nimbuwah Complex of the Oenpelli district may be correlated with quartzite of the Koolpin Formation equivalent mapped in the Cahill Sheet area (Needham & Smart, 1972). The dip of the quartzite bands, which is generally northeast, suggests they may form part of the eastern limb of a large recumbent synclinal structure.

In the Migmatite Zone and Granitoid Core of the Complex, massive rocks, and those with complicated interpenetration fabrics, do not reflect the regional trend but suggest increased structural disturbance during migmatization. However, the banded migmatites display a predominant 140° foliation, dipping south to southwest. Overall the Complex displays an approximate concentric structure, which is reflected by the distribution of the various zones and may indicate diapiric growth of the Nimbuwah Complex during its formation.

Recumbent isoclinal folding predominantes within the Fisher Creek Siltstone and Transitional Zone, and is less commonly developed in the Lit-par-lit Gneiss Zone. The folding is best exposed along the northern margin of the Oenpelli Massif, where fold crests are normal to the strike of the schistosity (S2) (Fig. 5b). Where folding is intense in the Lit-par-lit Gneiss Zone, S2 may be isoclinally folded to form S3 (Fig. 5d). An intermediate fold style (open-folded S2, Fig. 5c) has been noted in phyllites near Jim Jim Falls (Needham et al., 1975).

The Fisher Creek Siltstone and Nimbuwah Complex are intruded by the 'Oenpelli Dolerite', a thick (up to 250 m) undulating sheet or series of Lopliths, whose rims can be traced continuously by outcrop and subcrop (from aeromagnetic interpretation); the dolerite forms a series of ellipsoidal basins in the south and west of the survey area. Farther north and east the structure of the dolerite is no longer apparent.

The Kombolgie Formation structure is related to the outcrop distribution of the 'Oenpelli Dolerite' - the dolerite formed long arcuate basement highs marking broad shallow basins in the pre-Kombolgie surface and the sandstone was deposited over them (Fig. 6b). Erosion of the sandstone proceeded faster where faulting and jointing was most developed, generally over the basement highs where the thinner veneer of sandstone was extensively fractured during periods of warping. Therefore in some places the edge of the sandstone is roughly parallel to re-exhumed basement highs (e.g. Map Plate 11).

Dips within the Kombolgie Formation are generally less than 5°, but dips up to 35° are apparent at some of the outer edges of the sandstone and along some faults. The steeper dips may be drag-folds developed adjacent to near-vertical dip-slip faults, or drape structures developed over highs in the pre-Carpentarian surface (mostly dolerite, or migmatite and granitoid rock of the Nimbuwah Complex.)

The Carpentarian and older rocks are extensively faulted in three prominent directions - east, northeast, and north to northwest. The easterly faults generally form master joints in the Kombolgie Formation sandstone, and can be traced as photolinear features through the Nimbuwah Complex. A strong easterly lineament along Cooper Creek, evident also as a major disruption of aeromagnetic patterns, probably represents an important fault.

The northeasterly trending faults play a major role in controlling the outcrop shape of the Kombolgie Formation, especially in the Goomadeer Sheet area (Map Plates 9, 10, 13). Fault breccias, slickensides, and steep dips occur along some of the fault scarps; the Kombolgie Formation sandstone shows vertical displacements up to 100 m along some of these faults.

The Nabarlek uranium deposit and the Black Rock uranium prospect both lie on north-northwest-trending structures (possibly the same structure, which probably continues along the northeastern coast of Cobourg Peninsula, and passes through Grant Island) (Hughes & Senior, 1973).

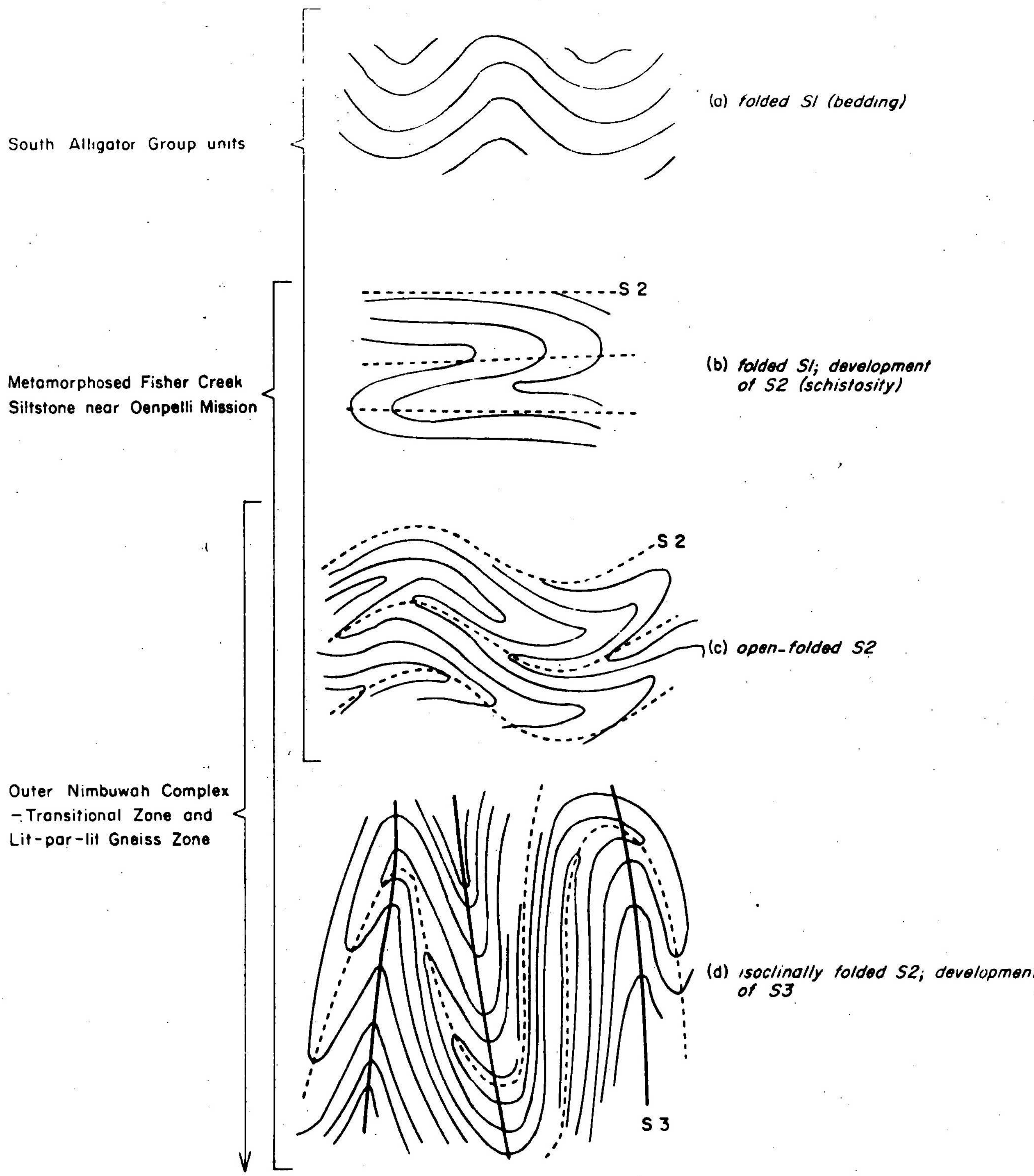
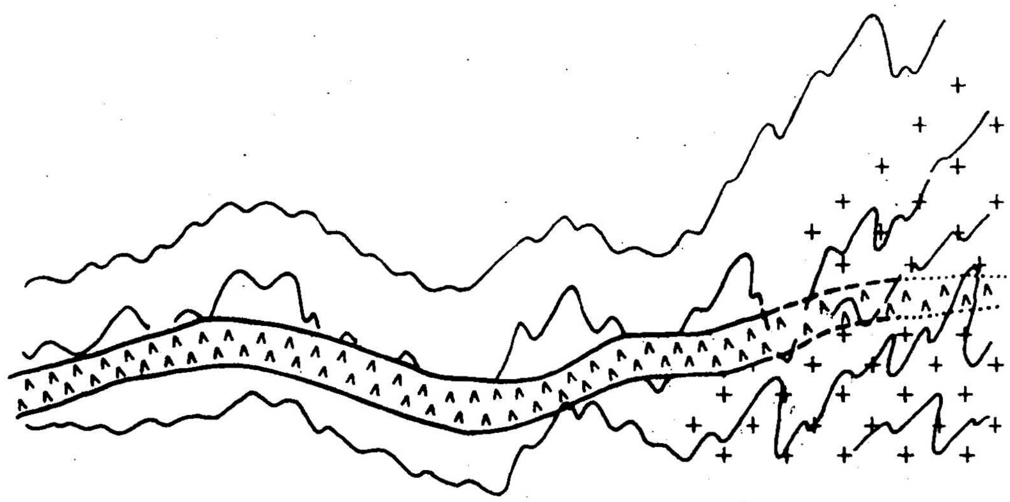
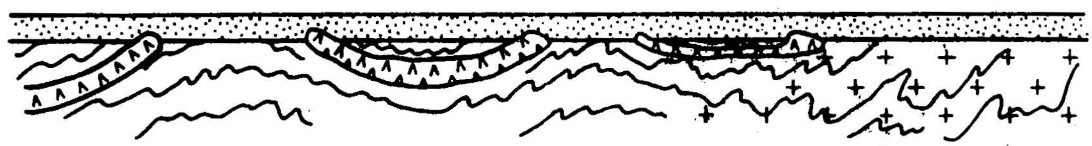


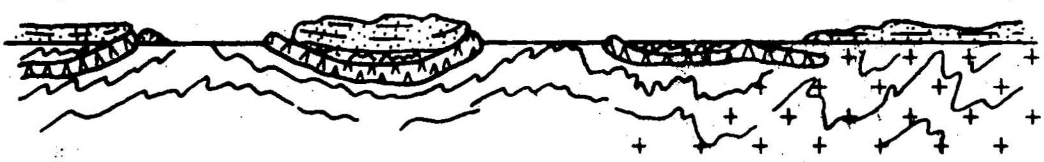
Fig. 5 Progressive fold styles with increasing regional metamorphism



(a) Intrusion of 'Oenpelli Dolerite' into Fisher Creek Siltstone and Nimbuwah Complex



(b) Deposition of Kombolgie Formation on pre-Carpentarian erosion surface



(c) Present-day topography

Fig. 6 Schematic diagram showing structural relationships between metamorphosed, South Alligator Group, Nimbuwah Complex, Oenpelli Dolerite, and Kombolgie Formation.

The Wessel Group sediments represent the margin of a shallow Upper Proterozoic basin of deposition, which extends east into the Milingimbi and Arnhem Bay 1:250 000 Sheet areas. The strata dip gently to the northeast; no major faults or folds have been distinguished within them. They unconformably overlie the Carpentarian and older rocks.

Subhorizontal Cretaceous strata overlie all older units; erosion remnants over the Kombolgie Formation suggest that Cretaceous sediments once covered at least part of the Arnhem Land Plateau. Cretaceous rocks which crop out on the Northern Plains and Arafura Fall close to the escarpment suggest that there has been little retreat of the escarpment since Mesozoic time.

Slight warping of the Cretaceous may have influenced the development of drainage patterns which have since been superimposed on older strata. Jungle Creek flows along the axis of a warp in Mesozoic rocks.

ECONOMIC GEOLOGY

Uranium

The only economic uranium deposit in the Oenpelli district is at Nabarlek, 32 km east of Oenpelli Mission (Map Plate 12). Its discovery in 1970 sparked off an intensive exploration program which has resulted in the discovery of three other uranium deposits to the southwest.

The Nabarlek deposit was detected by Queensland Mines Ltd as a first-order radiometric anomaly located by an airborne radiometric survey. Other anomalies, mostly lower-order ones, were also detected. Many of these were pinpointed on aerial photographs using a helicopter-borne scintillometer, and then located on the ground.

Of the airborne radiometric anomalies investigated by Union Carbide (Australia & New Zealand Exploration) only the Black Rock prospect has revealed sufficient uranium mineralization to warrant further investigation. The Tadpole prospect in the same exploration lease was shown by drilling to be only a surface anomaly within laterite. Several of the drill cores from this prospect have been donated to BMR. Auger drilling on several other total-count anomalies has revealed that the surface radioactivity is due mainly to thorium.

The major uranium deposits of the Cahill 1:100 000 Sheet area are all found in similar geological settings i.e. in Koolpin facies rocks adjacent to the margins of the Nanambu Complex (Needham & Smart, 1972). Unlike these deposits, the Nabarlek deposit and Black Rock prospect lie within a migmatite complex, not marginal to one.

At Nabarlek the ore is in a north-northwest-trending brecciated and mylonitized cataclastic zone about 100 m wide in schist, amphibolite, and gneiss of the Nimbuwah Complex. Rocks adjacent to and along part of this structure are mineralized, and are strongly altered to chlorite, hematite, sericite, and quartz as a result of possible cataclastic effects or the influence of hydrothermal solutions, or both.

The foliation of the host rocks is consistently flat-lying, or it dips at very low angles to the east. The host rocks are part of a recumbent isoclinally folded sequence, and are considered to represent part of the Lit-par-lit Gneiss Zone of the Nimbuwah Complex. Below the orebody the host rocks are intruded by the 'Oenpelli Dolerite', which is 250 m thick and dips at 20° to the southwest. Two hundred metres beneath the dolerite a relatively homogeneous coarse altered pink feldspar granite, the 'Narbarlek Granite', has been intersected. The granite crops out 8 km east of Nabarlek, and may be a late-stage intrusion of anatectic origin associated with the Nimbuwah Complex.

At Nabarlek, massive pitchblende occurs within one metre of the surface, where it is coated with gummite and other secondary minerals such as sklodowskite, saleeite and torbernite. Pitchblende, the chief ore mineral, with accessory galena and chalcopyrite, forms massive pods and lenses within the cataclastic zone. The pods are surrounded by haloes of disseminated pitchblende and secondary minerals. The ore pinches out at depth above the 'Oenpelli Dolerite'; however, some small veins of pitchblende are found in the upper part of the dolerite body.

The geological setting at the Black Rock prospect (Map Plate 2) is very similar to that of the Nabarlek deposit. The host rocks are of higher regional metamorphic grade than those at Nabarlek, and lie within the Migmatite Zone of the Nimbuwah Complex. They consist mainly of quartz-amphibole-biotite schist interbedded with biotite-hornblende granitic gneiss, but near the prospect they are strongly chloritized. The mineralization appears to be localized along a northwest- trending cataclastic zone which can be traced as photolineaments to the southeast. The mineralization has been found only on the eastern side of this brecciated and mylonitized zone, where it is underlain by the 'Oenpelli Dolerite', which is about 130 m thick.

Alteration of the gneiss and schist is attributed to hydrothermal or cataclastic effects, or both, but not to a contact effect of the dolerite, which is also chloritized adjacent to the structure. The southern end of the prospect is covered by Kombolgie Formation sandstone.

The similarity of the geological settings at Nabarlek and Black Rock suggest a similar genesis. An origin involving either the 'Oenpelli Dolerite' or the Kombolgie Formation as source rocks is not favoured as both are uranium-deficient. The 'Oenpelli Dolerite' is present at depth over most of the Oenpelli district so the presence of dolerite near the mineralized areas is of little significance. We believe that the spatial distribution of prospects and deposits close to Kombolgie Formation sandstone is coincidental, and is due to airborne radiometric techniques (which have been the basis of all uranium exploration in the region to date) being successful only in areas where Cainozoic cover is limited or absent, namely adjacent to the sandstone escarpment.

The uranium deposits of this area and the Cahill Sheet area are all located in cataclastic zones. The uranium was probably derived from a nearby source, possibly being 'sweated out' of the rock pile during migmatization. The deposits of the Cahill Sheet area are located within Koolpin Formation equivalent and are stratigraphically controlled. Ridges of quartzite within the Oenpelli area, possibly correlatives of similar quartzites within Koolpin Formation equivalent of the Cahill Sheet area (e.g. near the Koongarra deposit), suggest that Nabarlek and Black Rock are similarly controlled, even though the original sedimentary character of the rocks has in the main been obliterated.

Ultrabasics

The poorly exposed ultrabasic rocks which crop out in deeply eroded channels, 16 km northwest of Ngara airstrip (lat. 12°08'S, long. 132°50'E; Plate 6) contain minor disseminated chalcopyrite and other sulphides. The possibility of nickel sulphides and chromite make these rocks worthy of further investigation.

Bauxite

Several pisolitic bauxite occurrences have been noted in the laterite profile which is developed on the Cretaceous sediments of Cobourg Peninsula (Hughes & Senior, 1973). Small areas of pisolitic laterite in the Wellington Range and East Alligator Sheet areas do not appear to be of sufficiently high quality to warrant further investigation.

Water

Surface water as billabongs and waterholes in seasonal rivers and creeks, and in springs, provides the major source of fresh water in the area. The high annual rainfall over the area replenishes this supply in the wet season. The water supply for Oenpelli Mission is obtained from shallow bores along creeks near the settlement. In most of the region plentiful supplies of water can be obtained from shallow bores.

GEOCHRONOLOGY

Specimens of the following units were collected with the use of a rock drill and explosives:

Nimbuwah Complex Plz_1, Plz_2, Plz_3

'Maningkorrirr Phonolite'

Nungbalgarri Volcanic Member

Specimens of 'Oenpelli Dolerite' and 'Nabarlek Granite' were collected from Nabarlek drill core.

The specimens were collected and are being analysed by R.W. Page (BMR). Specimens of the Nungbalgarri Volcanic Member and 'Nabarlek Granite' may be unsuitable for dating because of alteration.

Collection of specimens had to be duplicated as the original specimens were destroyed by fire. Specimens collected from the Cahill and Jim Jim Sheet areas were described by Needham et al. (1975).

ACKNOWLEDGEMENTS

We would like to thank the following companies for their assistance and hospitality during the field season: Australia and New Zealand Exploration, McIntyre Mines and Ocean Resources, and Queensland Mines Ltd. We thank them especially for giving us copies of their aeromagnetic, radiometric, photogeological, and geological maps, and the many useful discussions held with their field geologists concerning the detailed and regional geology of the uranium province.

We also thank the people of Oenpelli Mission, for the hospitality and co-operation they afforded during our period of work in the region, and for the use of facilities at the mission.

REFERENCES

ALLEN, J.R.L., 1963 - The classification of cross-stratified units with notes on their origin. Sedimentology, 2, 93-114.

CHRISTIAN, C.S., & STEWART, G.A., 1953 - General report on a survey of the Katherine-Darwin Region, 1946. SIRO Land Res. Ser. 1.

DUNN, P.R., 1962 - Alligator River, N.T. - 1:250 000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes D53/1.

DUNN, P.R., 1963 - Urapunga - 1:250 000 Geological Series Bur. Miner. Resour. Aust. explan. Notes SD53/10.

ESKOLA, P., 1948 - The problem of mantled gneiss domes. Quart. J. geol. Soc. Lond. 104, 461-76.

HORSFALL, K.R. & WILKES, P.G., in prep. - Airborne magnetic and radiometric survey of the Cobourg Peninsula, Alligator River, and Mount Evelyn (part) 1:250 000 Sheet areas, N.T., 1971-2. Bur. Miner. Resour. Aust. Rec. (unpubl.).

HUGHES, R.J., & SENIOR, B.R., 1973 - Progress Report on the geology of the Bathurst Island, Melville Island, Cobourg Peninsula, and Fog Bay 1:250 000 Sheet areas. Bur. Miner. Resour. Aust. Rec. 1973/52 (unpubl.).

HUGHES, R.J., & SENIOR, B.R., 1974 - New stratigraphic names for Cretaceous and Cainozoic units of Bathurst and Melville Islands and Cobourg Peninsula, N.T. Aust. Oil Gas Rev., 20, 2, 10-17.

McDOUGALL, I., DUNN, P.R., COMPSTON, W., WEBB, A.W., RICHARDS, J.R. & BOFINGER, V.M., 1965 - Isotopic age determinations on Precambrian rocks of the Carpentarian region, Northern Territory, Australia. J. geol. Soc. Aust., 12, 67-90.

MEHNERT, K.R., 1968 - MIGMATITES AND THE ORIGIN OF GRANITIC ROCKS. Amsterdam, Elsevier.

NEEDHAM, R.S., & SMART, P.G., 1972 - Progress report, Alligator River Party, N.T., 1971 Bur. Miner. Resour. Aust. Rec. 1972/1 (unpubl.).

NEEDHAM, R.S., SMART, P.G., & WATCHMAN, A.L., - 1973 - Regional geology of the Alligator Rivers uranium province, Northern Territory, Australia. Bur. Miner. Resour. Aust. Rec. 1973/64.

NEEDHAM, R.S., SMART, P.G., & WATCHMAN, A.L., 1975 - Progress report, Alligator River Party, N.T., 1972 (Jim Jim region). Bur. Miner. Resour. Aust. Rec. 1975/31 (unpubl.).

PLUMB, K.A., SHERGOLD, J.H., STEFANSKI, M.Z., in prep - The significance of recently discovered Middle Cambrian trilobites in the Arafua Basin, Northern Territory.

RIX, P., 1964 - Junction Bay, N.T., - 1:250 000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SC/53-14.

RIX, P., 1965 - Milingimbi, N.T. - 1:250 000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes 30/53-2.

ROBERTS, H.G. & PLUMB, K.A., 1964 - Mount Marumba, N.T. - 1:250 000 Geological Series. Bur. Miner. Resour. Aust. explan. Notes SD/53-6.

RUKER, R.A., 1962 - Milingimbi. Bur. Miner. Resour. Aust. photogeol. Ser. SD/53-2 (unpubl.).

STEWART, J.R., 1959 - Proterozoic igneous rocks in the Katherine-Darwin region, Northern Territory. M.Sc. Thesis, Univ. New England (unpubl.).

STORY, R., WILLIAMS, M.A.J., HOOPER, A.D.L., O'FERRALL, R.E., & McALPINE, J.R., 1969 - Lands of the Adelaide - Alligator Area, Northern Territory, CSIRO Land Res. Ser. 25

WALPOLE, B.P., CROHN, P.W., DUNN, P.R., & RANDAL, M.A., 1968 - Geology of the Katherine-Darwin Region, Northern Territory. Bur. Miner. Resour. Aust. Bull. 82.

WHITEHOUSE, F.W., 1940 - Studies in the late geological history of Queensland. Univ. Qld Dep. Geol. Pap. 2(1).

WILKES, P.G., 1975 - Results of radiometric surveys in the Alligator River and Cobourg Peninsula area of the Northern Territory. Proc. Aust. Inst. Min. Metall. ann. Conf., Adelaide, 1975.

WILLIAMS, M.A.J., 1969 - Geology of the Adelaide-Alligator area. In Lands of the Adelaide- Alligator area, Northern Territory. CSIRO Land Res. Ser. 25

WINKLER, H.G.F., 1967 - PETROGENESIS OF METAMORPHIC ROCKS. Berlin, Springer-Verlag.

APPENDIX 1: Changes in Stratigraphic Nomenclature

NIMBUWAH COMPLEX: Change of name approved (extracted from Needham et al. 1973)

Reasons: This unit was first named the Nimbuwah Granite by Dunn (1962), but the name was changed to Nimbuwah Complex by Rix (1965), when 'it was found to include both gneissic and massive granitic rocks'. We now recognize the Complex as an extensive mantled migmatite dome composed of diatectic (granitic) and metatectic (banded or differentiated) migmatites, gneiss, schist, basic amphibolite, and quartzite. Therefore we should like to retain the name Nimbuwah Complex, but alter its description, and take this opportunity to formalize the name.

Type locality and name: The name is derived from Nimbuwah Rock, a prominent pinnacle consisting of Kombolgie Formation sandstone overlying Nimbuwah Complex rocks. We should like to register the type area as the hill situated at lat. 12°09'40"S, long. 133°35'30"E, where there are extensive exposures of diatectic and metatectic migmatites, intruded by phonolite dykes.

Extent: The Nimbuwah Complex crops out east of the East Alligator River, mostly north of the Arnhem Land escarpment; it continues east to the vicinity of Nungbalgarri Creek, where it is overlain by rocks of the Proterozoic Wessel Group. It continues north to the coast, and is masked by Kombolgie Formation sandstone and Mesozoic strata at the base of the Cobourg Peninsula.

Age: Lower Proterozoic, formed by migmatization of Lower Proterozoic sediments.

Name first published: Needham, R.S., Smart, P.G., & Watchman, A.L., 1974- A reinterpretation of the geology of the Alligator River Region, N.T. Search 4(5), 397-9.

'OENPELLI DOLERITE': name approved, not yet published

Derivation of name: Oenpelli Mission 12°20'S, 133°04'E, Alligator River 1:250 000 Sheet area.

Distribution: As arcuate ridges over 30 000 km^2 in the Alligator River, Mount Evelyn, Milingimbi, and Cobourg Peninsula 1:250 000 Sheet areas between 11°45'S and 13°30'S, and 132°30'E and 134°00'E.

Type locality: Graveside Gorge, 13°18'S, 132°34'E. A ridge of differentiated dolerite 150 m high trending northeast along south side of gorge. Differentiates include porphyritic olivine dolerite, ophitic dolerite and ophitic gabbro with igneous lamination, granophyric dolerite, and syenite.

Lithology: A roughly symmetrically differentiated dolerite intrusive dyke. Central part is igneous-laminated ophitic dolerite commonly with ophitic gabbro locally; granophyric dolerite, granophyre, and syenite differentiates as lenticular bodies. Central part grades upwards and downwards with decrease in groundmass grainsize to porphyritic olivine dolerite containing porphyrocrysts of saussuritized pale green plagioclase less than 5 cm. A chilled margin is rarely apparent. Gabbro pegmatite is rarely developed adjacent to the upper chilled margin (see Fig. 4).

Thickness: Maximum thickness drilled 250 m. Arcuate ridges probably are exposed rims of roughly ellipsoidal basins, which may be part of a large undulating sheet of dolerite or mark individual lopoliths; the latter alternative is supported by a general thickening of the dolerite towards the centres of the basins. There are also occasional narrow dykes (10 cm to 1 m) of 'Oenpelli Dolerite' (porphyritic olivine dolerite) with sharp margins which are probably offshoots from the main intrusive body.

Relations: Intrudes Nanambu and Nimbuwah migmatite complexes. Intrudes all Lower Proterozoic sedimentary and metamorphic units. Forms basement highs to, and unconformably overlain by, Carpentarian Kombolgie Formation sandstone. Also intrudes Jim Jim Granite.

Boundary criteria: Generally sharp contacts with country rock, which is usually hornfelsed. In central parts of Nimbuwah Complex, however, boundaries commonly grade into country rock which was assimilated by the dolerite during intrusion.

Age and evidence: 1720 m.y. Total-rock Rb-Sr isochron of 1718 ± 65 m.y. R.W. Page (pers. comm).

Synonymy: Walpole et al. (1958) misinterpreted some exposures as either Zamu Complex or Nungbalgarri Volcanic Member - remainder of exposures were unnamed dolerite.

'MANINGKORRIRR PHONOLITE': name approved, not yet published

Derivation of Name: Maningkorrirr - a small aboriginal settlement on the Goomadeer River at 12°06'S, 133°41'E, Milingimbi 1:50 000 Sheet area.

Distribution: 50 km^2, centred 8 km ENE of Jungle Creek headwater, and east of the low Mesozoic escarpment which marks the western edge of the Goomadeer River catchment.

Type locality: 12°9'45"S, 133°35'25"E; on Oenpelli-Maningrida track 1 km east of Mesozoic escarpment, and 9 km west of the Maningkorrirr turnoff. The track crosses 3 phonolite dykes trending NE, SE and SSE.

Lithology: Fine to medium to porphyritic grey-green dyke rock. Phenocrysts of euhedral anorthoclase and sanidine tablets, and zoned aegirine-augites 5 mm to 3 cm. Some pyroxenes are rimmed by a pleochroic green sodic amphibole, which also occurs in the groundmass. Groundmass is generally strongly altered, and consists essentially of sanidine-anorthoclase, aegirine-augite, biotite, titanomagnetite, and accessory sphene.

Thickness: Less than 1 m wide, generally 30-60 cm wide, and up to 1 km long.

Relationships and boundary criteria: Straight parallel-sided steeply dipping dykes with sharp boundaries cutting granitoid migmatite of the Nimbuwah Complex. Typically hybrid and contain xenoliths of the country rock.

Age & evidence: About 1350 m.y.; total-rock Rb-Sr isochron. K-Ar data yield unrealistic spread of dates from 2100 to 600 m.y. R.W. Page (pers. comm., 1974).

APPENDIX 2: Auger drilling

Auger Traverse 8

Traverse 8 was laid out in a northerly direction 6 km west of Nimbuwah Rock; the holes were drilled up to a depth of 10 m, and spaced 0.5 km apart. Examination of rock chips showed that the main rock type was biotite-quartz-feldspar gneiss which was variably weathered. The depth of weathering increased southwards along the traverse as the rocks became more schistose. This may indicate that the transitional margin of the Nimbuwah Complex is nearby. Cuttings from hole 10 contained chips of dolerite, confirming surface indications (vegetation and soil) that a dolerite is present at depth. All holes were logged by a gamma ray probe; the measurements were generally low and were unrelated to the lithology.

AUGER TRAVERSE 8

HOLE NO.	DEPTH M.	LITHOLOGY	MAX. RAD. cps	MAX. RAD. depth m.	REMARKS
1	9.1	Musc-Biot-Qz-Fs Gns	10	7.3	Qz at hole bottom
2	10.4	Biot-Qz-Fs Gns	11	9.1	Sch frags 4.6-6.1 m.
3	10.4	Biot-Qz-Fs Gns	10	5.5	
4	9.1	Biot Sch, Biot-Qz-Fs Gns	10	4.9	
5	9.1	Biot-Qz-Fs Gns	8	7.3	
6	9.1	Biot-Qz-Fs Gns	12	7.9	max.rad. at TPD.
7	9.1	Biot-Qz-Fs Gns	11	7.9	
8	9.1	Biot-Qz-Fs Gns	16	3.0	several large Fs
9	9.1	Qz-Fs-Gns	12	1.2	
10	9.4	Dl	10	6.1	
11	9.1	Qz-Fs Gns	16	1.2	several large Fs
12	9.1	Biot-Qz-Fs Gns (small Fs Augen)	12	1.2	wthrd opc Mig 4.6-9.1 m
13	9.1	Qz-Fs Gns	14	6.1	
14	7.6	Qz, ck, Fs	12	5.8	max.rad. at TPD
15	9.1	Biot-Qz-Fs Gns	22	1.8	
16	9.1	Biot-Qz-Fs Gns (large Fs augen)	16	7.9	max.rad. at TPD opc Mig

AUGER TRAVERSE 8 (Continued)

HOLE NO.	DEPTH M.	LITHOLOGY	MAX. RAD. cps	MAX. RAD. depth m.	REMARKS
17	9.1	Biot-Qz-Fs Gns	8	1.2	
18	9.1	Biot-Qz-Fs Gns	12	2.4	
19	7.6	Qz, faulted Gns	22	3.0	si fault
20	7.6	strongly wthrd Gns	10	0	
21	9.1	Biot-(Qz)-Fs Gns	12	4.9	
22	9.1	Biot-Qz-Fs Gns	8	7.3	
23	9.1	Qz-Fs Gns (minor Biot)	25	6.1	
24	9.1	Ck, Fs, fed	16	2.4	
25	6.1	Sand, ck Fs, Qz	5	4.9	
26	9.1	" " " fed	7	4.9	
27	9.1	Sand, ck Fs	15	1.2	
28	9.1	" " ", Qz	14	0.6	

TRAVERSE 9

Traverse 9 was drilled along a track (roughly E-W) starting near the East Alligator River and running east to the Ngara airstrip access road. The holes were drilled up to a depth of 10 m, and spaced 0.5 m apart. The aim of this traverse was to see if any variation could be found within the Fisher Creek Siltstone, which crops out to the north and south of the traverse, trends roughly north, and dips steeply. The traverse was unsuccessful as no Lower Proterozoic rocks were reached. Most of the holes bottomed in Cainozoic ferruginous sand derived from lateritized Cretaceous sandstone and siltstone which crop out near the traverse; Kombolgie Formation sandstone may have been the source of some of the sand, as Hole 10 bottomed in white porous sandstone. The traverse was discontinued after 11 holes were drilled.

TRAVERSE 9

HOLE NO.	DEPTH M.	LITHOLOGY	MAX. RAD. cps	MAX. RAD. depth m.	REMARKS
1	6.1	wthrd Dl	10	5.0	'Oenpelli Dolerite' porphyritic phase
2	7.6	Sand	10	5.5	Czs
3	7.6	fe sand, some qtz sand	8	1.2	)
4	9.1	fe sand	10	3.7	)
5	6.1	clayey sand, fes sand	11	2.4	) Czs, some Cretaceous sandstone. Minor Kombolgie Formation sandstone?
6	7.6	clayey sand, fes sand	10	2.0	)
7	6.1	fe sand, minor clayey sand	13	1.2	)
8	6.1	fe sand minor clay	12	1.2	)
9	6.1	fe sand	12	1.2	)
10	2.4	fe sand, qtz sand	8	2.4	Stopped in Kombolgie sandstone
11	10.7	fe sand	12	1.0	

TRAVERSE 10

This traverse started on a creek 9 km northwest of Ngara airstrip, and follows a grid line to the east finishing on the Murgenella road. The holes were drilled to a depth of 10 m, and spaced 0.5 km apart.

The aim of the traverse was to determine the position of the boundary between the Lit-par-Lit Gneiss Zone, the Transitional Zone, and the Fisher Creek Siltstone. The first four holes were drilled in schist and amphibolite of the Fisher Creek Siltstone. Holes 5 to 8 are considered to have been in the Transitional Zone as the rocks intersected were gneissic (i.e., metamorphic feldspar replacing muscovite). The 'Oenpelli Dolerite' must be at shallow depth throughout most of the area; it was intersected in holes 9, 10, 11, 16, 18, and 19, but does not crop out along the traverse. Holes 11 to 20 revealed a variety of gneissic rock types of the Lit-par-Lit Gneiss Zone; these include leucogneiss and banded biotite gneiss. Variations in down-hole radioactivity were usually relatable to changes in rock type. Dolerite was always low (2 to 15 cps); schist of the Fisher Creek Siltstone was also low (12-16 cps); gneiss of the Lit-par-Lit Gneiss Zone gave the highest background values (12-35 cps), as might be expected. None of these values are considered anomalous (cf. Appendix 2 of Needham & Smart, 1972).

TRAVERSE 10

HOLE NO.	DEPTH M.	LITHOLOGY	MAX. RAD. cps	MAX. RAD. depth m.	REMARKS
1	7.0	Qz-Musc Sch	16	0.6	Fisher Creek Siltstone
2	9.1	Qz-Hble-Fs Am	12	0.6	"
3	10.4	Qz-Musc-Biot Sch	14	5.5	"
4	10.4	Qz-Musc Sch	14	1.0	"
5	4.6	Musc-Fs Qt	14	1.8	Transitional Zone of Nimbuwah Complex
6	9.1	Biot-Musc-Fs Sch	18	6.1	"
7	9.1	Qz-Musc-Biot Sch (minor Fs)	20	4.3	"
8	9.1	Qz-Musc-Biot Sch (minor Fs)	20	5.5	"
9	9.1	Fs, Chl, Px, opaques wthrd Dl	8	0.3	'Oenpelli Dolerite'
10	6.1	wthrd Dl	12	0.3	"
11	7.0	minor micas. Qz-Fs Lgns?	12	5.5	Lit-par-lit Gneiss Zone
12	9.1	Musc-Qz-Fs Lgns	14	5.5	"
13	9.8	Musc-Fs-Qz Lgns	16	0.6	"
14	10.1	Musc-Biot-Qz Fs Gns	16	1.2	"
15	7.0	Musc-Biot-Qz-Fs Gns	10	5.5	"

TRAVERSE 10 (Continued)

HOLE NO.	DEPTH M.	LITHOLOGY	MAX. RAD. cps	MAX. RAD. depth m.	REMARKS
16	6.7	Chl, Fs, Px; wthrd Dl	14	4.3	'Oenpelli Dolerite'?
17	9.1	Qz, Mic, Lat	4	1.8	inconclusive, Czl
18	6.1	Qz-Fs-Mic Sch, Fs, Px, opaques	25	0.6	hole bottomed in 'Oenpelli Dolerite'. Lit-par-lit Gneiss Zone
19	10.1	Qz-Fs Lgns (minor micas)	35	1.2	Hole bottomed in dolerite Lit-par-Lit Gneiss Zone
20	3.7	Qz-Fs Lgns (minor micas)	25	2.4	"

AUGER TRAVERSE 11

The traverse started 0.5 km north of hole 8 on Traverse 10, and followed a track to the north-northeast for the first 5 holes (2.0 km). It then headed west to hole 7 (0.7 km), south 0.5 km to hole 8, west to hole 11 (1.5 km) and north to hole 12 (0.5 km). Holes were drilled to a depth where recognizable weathered bedrock was intersected (about 13 m). The aim of the traverse was to determine the position of the Fisher Creek Siltstone/Nimbuwah Complex boundary to the north and west of the boundary on Traverse 10. The traverse was not completed, and the Fisher Creek Siltstone was not intersected in any hole. The boundary, therefore, must lie west of holes 11 and 12. Two small hills of weathered and lateritized schist 1.5 km southwest of hole 12 appear to be Fisher Creek Siltstone. The position of the boundary, therefore, lies between hole 12 and these hills, and must trend roughly north - i.e., parallel to the regional foliation.

Values obtained for down-hole radioactivity were similar to those for equivalent rock types on Traverse 10 (i.e., dolerite, 2-15 cps; gneiss and leucogneiss, 18-36 cps).

TRAVERSE 11

HOLE NO.	DEPTH M.	LITHOLOGY	MAX. RAD. cps	MAX. RAD. depth m.	REMARKS
1	16.5	chips Dl; Ol, Fs, Px, opaques	18	3.0	'Oenpelli Dolerite'
2	16.5	musc Lgns; Fs-Qz-Musc-Biot Sch	36	6.7	Lit-par-Lit Gneiss Zone
3	12.2	Qz-Fs-Musc-Biot Sch	34	3.7	"
4	9.8	Musc-Biot Gns chips	30	7.9	"
5	9.1	Musc-Biot Gns chips; Qz-Fs-Biot Sch chips	18	4.9	"
6	10.4	Qz-Fs-Musc-Biot Sch chips	24	3.7	"
7	14.6	Ol, Chl, Fs, Px, opaques; Dl	12	1.8	'Oenpelli Dolerite'
8	12.2	wthrd Musc-Biot Lgns chips	26	9.1	Lit-par-lit Gneiss Zone
9	7.9	opaques, Px, Fs, Chl; Dl chips	15	4.9	'Oenpelli Dolerite'
10	14.0	chips banded Biot Gns; Fs-Qz-Musc-Biot Sch	35	1.8	Lit-par-lit Gneiss Zone
11	6.1	Lat; latd Musc-Biot-Qz-Fs Gns	2	4.3	Laterite on 'Oenpelli Dolerite' in Lit-par-lit Gneiss Zone

APPENDIX 3: List of abbreviations used in Plates 1 - 13 and Appendix 2

abnd	abandoned
Ae	agate
ag	agmatic
altd	altered
Am	amphibolite
Aspy	arsenopyrite
assim	assimilated
aug	augen
Biot	biotite
biot	biotitic
Bld	boulder
blky	blocky
bndd	banded
brecd	brecciated
c	coarse
Chl	chlorite
chl	chloritic
Cgl	conglomerate
Ck	kaolin
ck	kaolinitic
dic	diktyonitic
dissmd	disseminated
Dl	Dolerite
d/t	diatexite
Exp	exposure
fe	ferruginous
fed	ferruginized

fldg	folding
fol	foliated
Frac	fracture
Fs	feldspar
fs	feldspathic
Ft	felsite
gar	garnetiferous
Gb	gabbro
Gns	gneiss
Gr	granite
gr	granitic
Grd	granitoid rock
grd	granitoid
Hble	hornblende
hble	hornblendic
hem	hematitic
hom	homogeneous
hyb	hybrid
id	idioblastic
iso	isoclinal
Lat	laterite
latd	lateritized
Lgns	leucogneiss
max	maximum
mi	micaceous
Mig	migmatite
m/t	metatexite
Musc	muscovite
musc	muscovitic
neb	nebulitic

o/c	outcrop
Ol	olivine
opc	ophthalmic
oph	ophitic
Peg	pegmatite
phl	phlebitic
po	porphyritic
pob	porphyroblastic
ps	psammitic
pty	ptygmatic
py	pyritic
Px	pyroxene
qb	quartz breccia
Qt	quartzite
qtz	quartzitic
Qz	quartz
qz	quartzitic
rad	radioactivity
Rub	rubble
scatd	scattered
Sch	schist
schl	schlieren
shd	sheared
si	silicified
Sltst	siltstone
Sst	sandstone
sti	stictolithic
sto	stromatic
tf	tuffaceous

67

To	tourmaline
TPD	total probe depth
Trav	traverse
vnd	veined
wthrd	weathered
Xen	xenolith

PLATE 1

Reference

CAINOZOIC	QUATERNARY		Qca	*Silt, mud, coastal alluvium*
			Qcp	*Coastal mud pans*
			Qcr	*Sand, shelly sand, coastal sand ridges*
			Qa	*Silt, clay, sand; terrestrial alluvium*
			Qs	*Unconsolidated sand: outwash and colluvial deposits*
			Qas	*Silt, clay: abandoned channel deposits*
			Qal	*Silt: levee deposits*
			Qf	*Black and brown humic soil and clay deposits*
			Czt	*Sandstone, quartzite, and schist rubble, sand: talus deposits*
			Czw	*Silt and clayey sand; colluvial deposits over deeply weathered Cretaceous sediments*
			Cza	*Sand, clay : partly stripped Czs*
			Czs	*Unconsolidated sand; clayey sand*
			Czl	*Laterite*
PALAEOZOIC MESOZOIC	LOWER TO UPPER CRETACEOUS	Bathurst Island Formation: Moonkinu Member	Kum	*Sublabile sandstone, mudstone, carbonaceous in part, calcareous and limonitic concretions; fossiliferous*
		Bathurst Island Formation: Marligur Member	Kla	*Poorly sorted quartzose sandstone, siltstone and mudstone, minor conglomerate: fossiliferous*
	LOWER CRETACEOUS		Kl	*Sandstone, ferruginous sandstone, siltstone, mudstone*
	CAMBRIAN	Marchinbar Sandstone	Ꞓwm	*Flaggy to massive thin-bedded quartz sandstone*
		Buckingham Bay Sandstone	Ꞓwb	*Massive to blocky white quartz sandstone*
PROTEROZOIC	ADELAIDEAN	Maningkorrirr Phonolite*	ph	*Phonolite, phonolitic trachyte dykes*
		Wurugoij Dolerite *	Pdw	*Fine to medium-grained ophitic dolerite*
	CARPENTARIAN	Kombolgie Formation	Phk$_2$	*Massive quartz sandstone, minor quartz greywacke and siltstone; cross-bedded, ripple-marked*
		Kombolgie Formation: Nungbalgarri Volcanic Member	Phn	*Basalt, amygdaloidal basalt, intercalated siltstone and tuffaceous sediments*
		Kombolgie Formation	Phk$_1$	*Quartz sandstone, minor quartz greywacke, siltstone conglomerate hematitic sandstone and brown ferruginous sandstone; cross-bedded, ripple-marked*
		Oenpelli Dolerite*	Pdo	*Porphyritic ophitic and granophyric dolerite; syenite differentiates*
	LOWER PROTEROZOIC	Nabarlek Granite*	Pgn	*Altered pink biotite granite*
			Plc	*Thin soil cover or regolith over undivided Lower Proterozoic units*
			Pl	*Undivided Lower Proterozoic units*
		Nimbuwah Complex	Plz$_c$	*Gneiss, migmatite, and schist, with thin soil cover*
			Plz	*Undivided gneiss, migmatite and schist*
			Plz$_1$	*Diatexite; foliated to homogeneous granitoid migmatite rocks*
			Plz$_2$	*Metatexite; heterogeneous migmatite with various penetration fabrics*
			Plz$_3$	*Lit-par-lit gneiss, biotite and garnet schist, basic amphibolite and quartzite*
			Plz$_4$	*Feldspathic biotite schist, banded schist and gneiss, quartzite, basic amphibolite*
		South Alligator Group: Fisher Creek Siltstone (metamorphic equivalent)	Plf	*Schist; micaceous, psammitic; chlorite schist; minor biotite schist, quartzite, micaceous quartzite*
		South Alligator Group: Koolpin Formation (metamorphic equivalent)	Plk	*Garnet biotite schist, feldspathic biotite schist and gneiss, quartzite, amphibolite, recrystallized dolomite and magnesite; graphitic shist, talc-tremolite schist*

Geological boundary
Fault
Fault, showing relative vertical movement (D / U)
Quartz-breccia-filled fault (qb)
Fault showing angle of dip (40)

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

Plunge of minor anticline
Plunge of fold axes
Strike and dip of axial plane of recumbent minor folds
Plunge of recumbent minor folds with strike and dip of axial plane
Fault zone
Shear zone

Strike and dip of beds, prevailing or unmeasured
Strike and dip of beds, measured
Strike and dip of beds, vertical
Strike and dip of beds, horizontal
Strike and dip of beds, curving dip

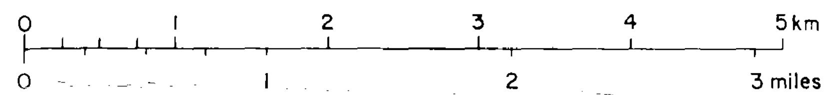
Photo-interpretation:
Dip < 5°
Dip < 15°
Trend lines
Trend lines showing prevailing dip of beds
Lineament
Joint pattern

Dip slope
Strike and dip of joint, unmeasured
Strike and dip of joint, measured
Metamorphic foliation, unmeasured
Metamorphic foliation, measured
Metamorphic foliation, vertical
Metamorphic foliation with plunge of lineation (crenulation)
Banding in igneous rocks, unmeasured
Banding in igneous rocks, measured
Banding in igneous rocks, horizontal
Direction of movement of sediment-bearing currents; x denotes cross bedding, r denotes ripple marks
Direction of movement of sediment-bearing currents sense unknown
Macrofossil locality } *( ) denotes sparse eg*
Plant fossil locality } *_ denotes abundant eg*
Dyke or vein; q quartz, ph phonolite, to tourmaline, a aplite

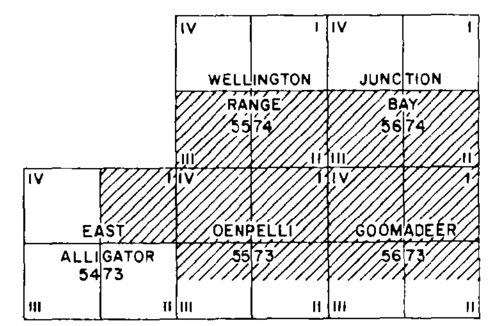
Unworked deposit
Prospect
U *Uranium*

Watercourse
Waterhole (WH)
Spring
Waterfall
Escarpment
Track
Airstrip
Homestead ('Mammawerre' HS)
Built up area
Fence
Trigonometrical station
Aboriginal reserve boundary
Extent of auger traverse

SCALE 1:50 000



1:100000 SHEET AREAS



PARTS OF THE EAST ALLIGATOR, WELLINGTON RANGE, JUNCTION BAY, GOOMADEER AND OENPELLI 1:100 000 SHEET AREAS NORTHERN TERRITORY

M(P) 605

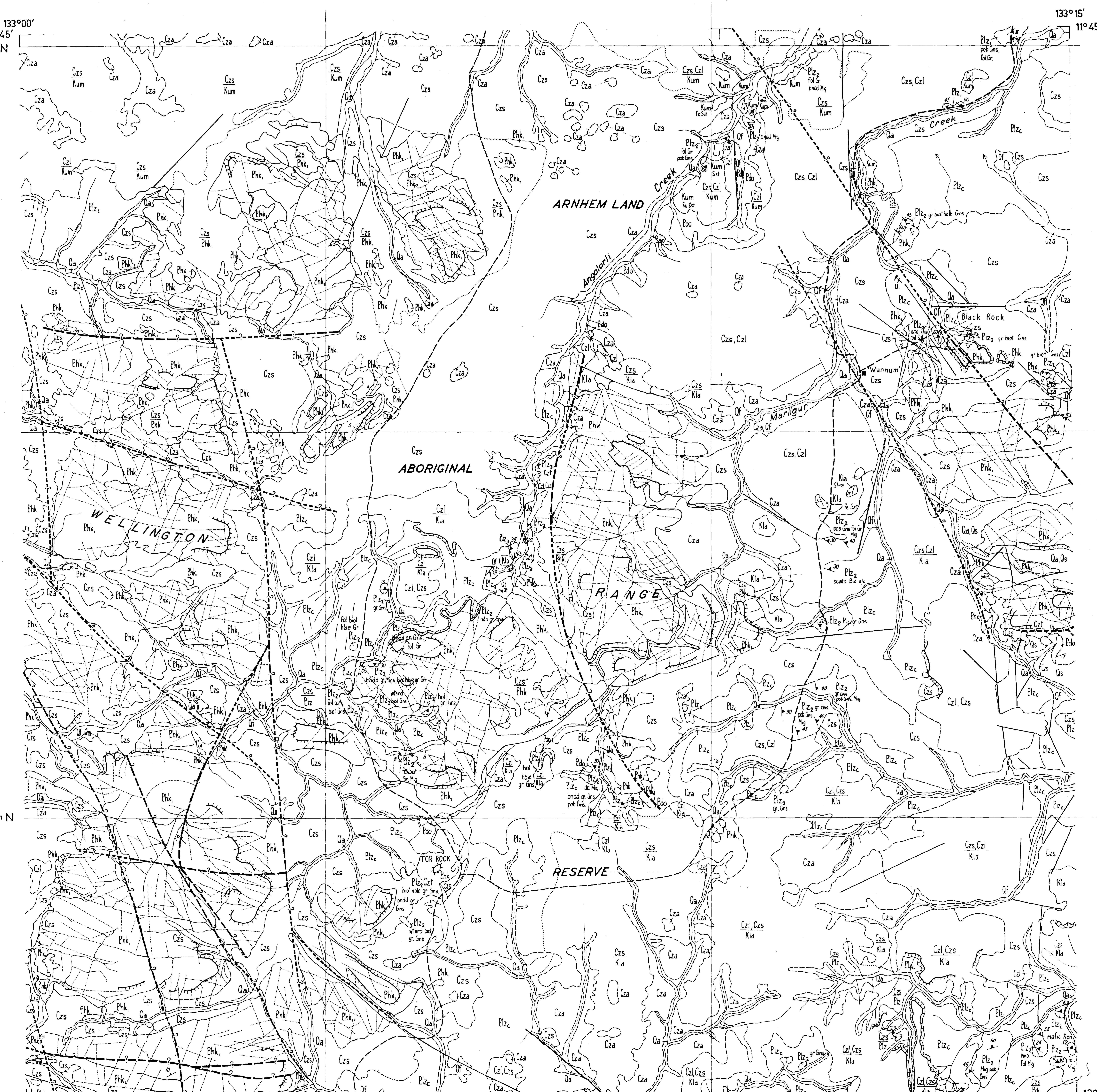


PLATE 2

WELLINGTON RANGE

1:50 000

GEOLOGY: P.G. SMART

COMPILED: P.H. FUCHS

Record 1975/39

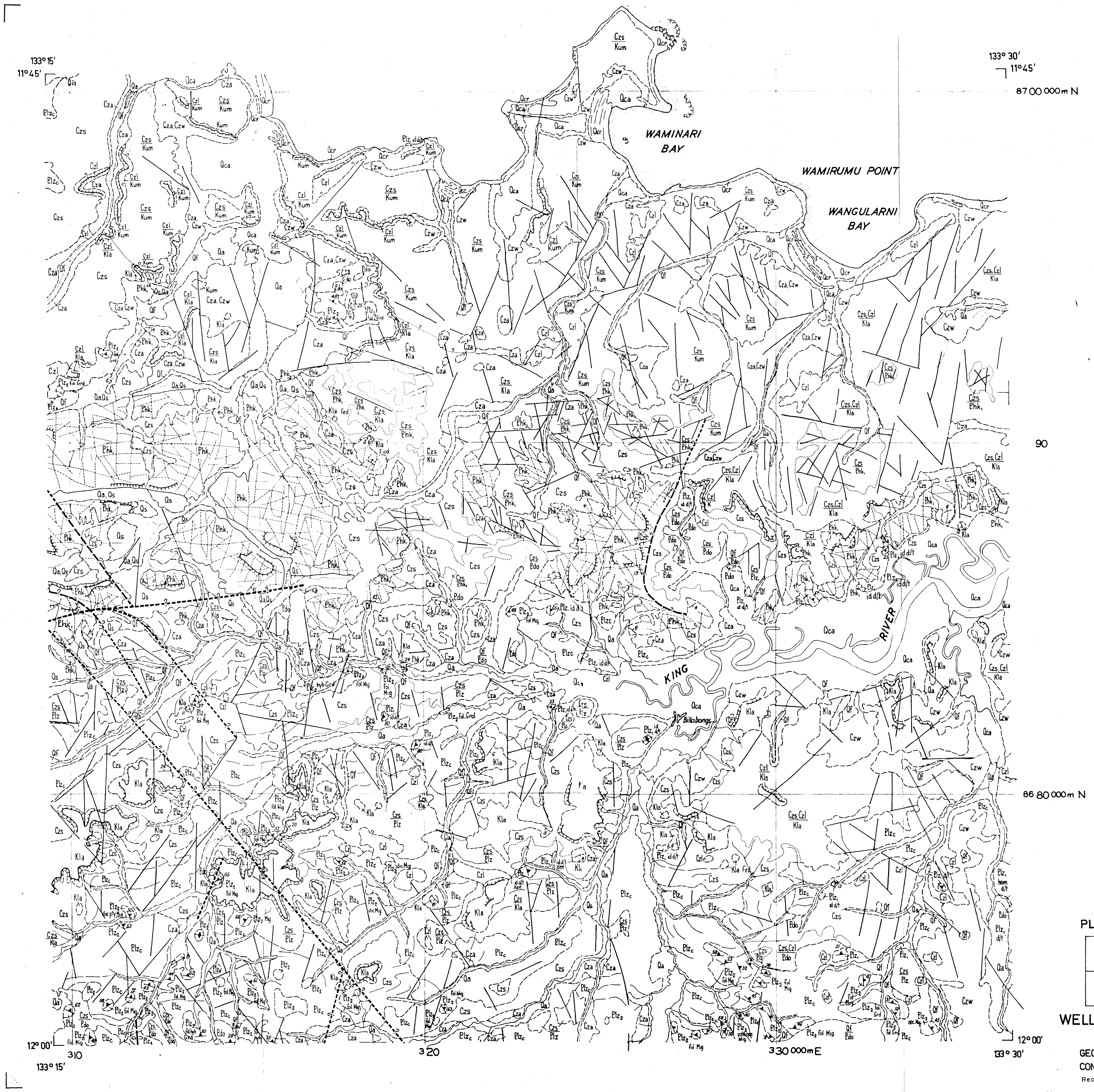
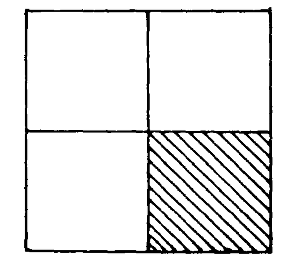


PLATE 3



WELLINGTON RANGE

1: 50 000

GEOLOGY: A. WATCHMAN

COMPILED: P.H. FUCHS

Record 1975/39

WELLINGTON RANGE S.E.
WELLINGTON RANGE S.E.

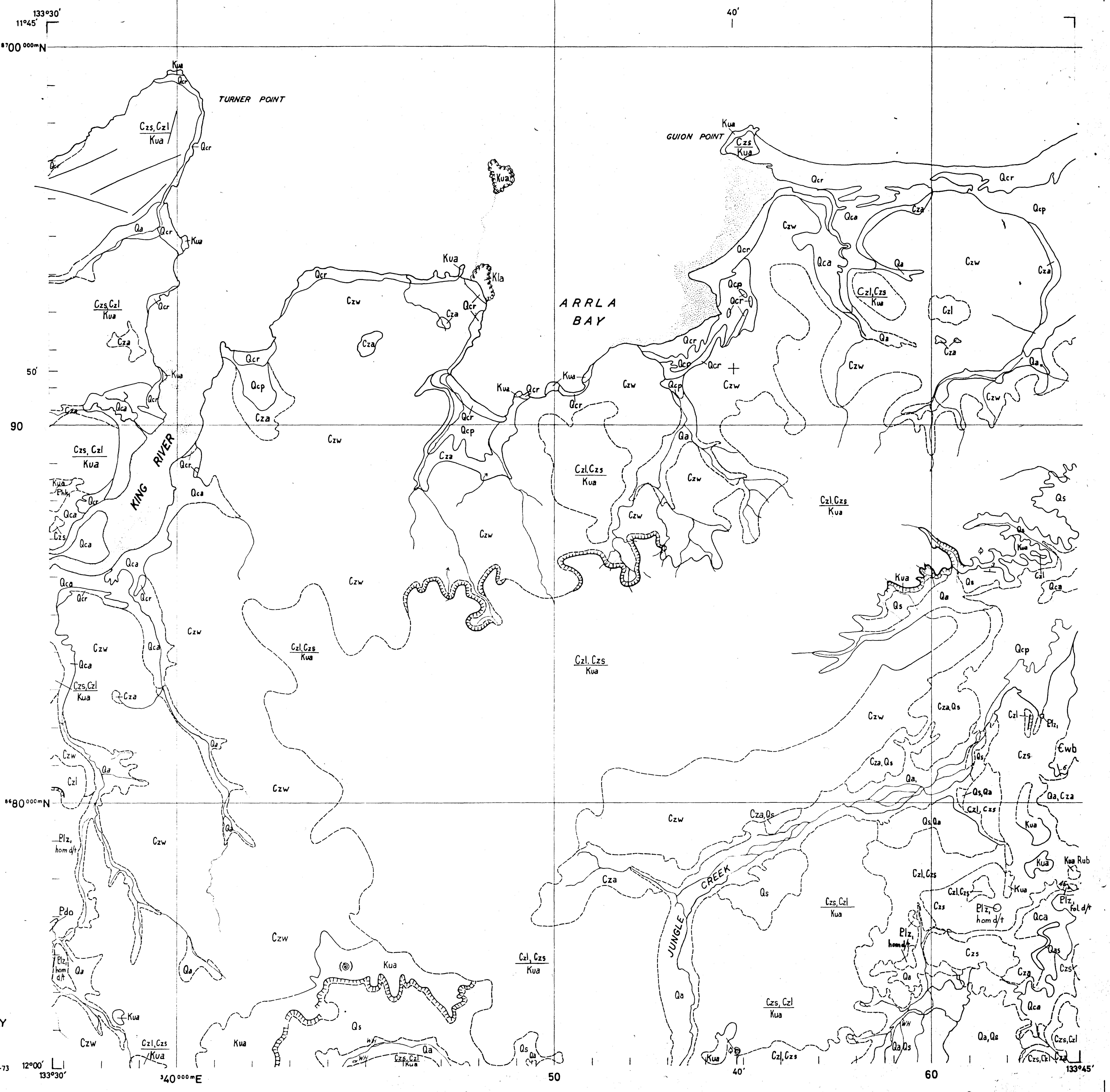


PLATE 4

JUNCTION BAY
1:50 000

Geology: R.S. Needham
Compiled: P. Lachlan 10-6-73

Record 1975/39

JUNCTION BAY SE

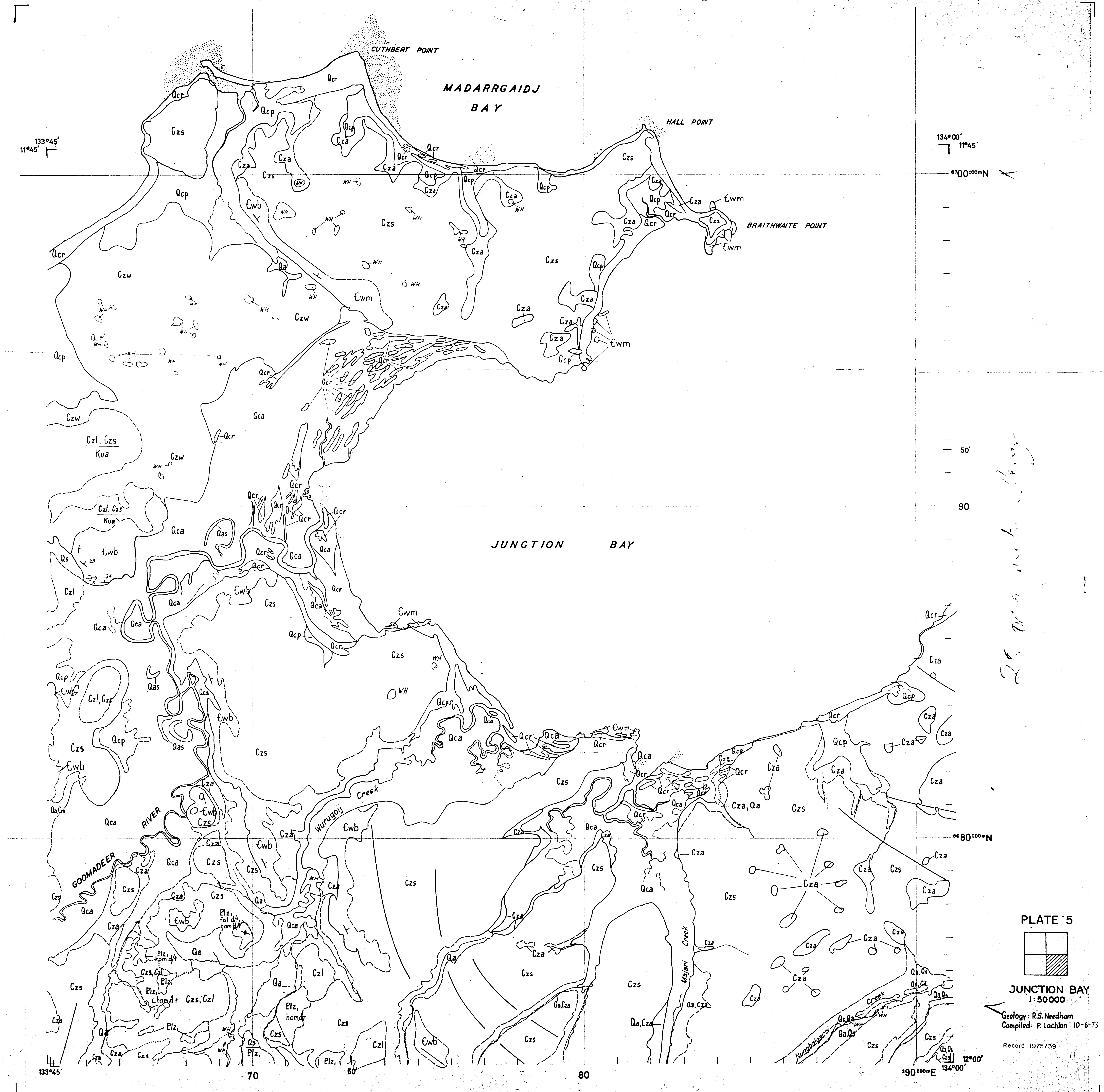


PLATE 5

JUNCTION BAY
1:50000

Geology: R.S. Needham
Compiled: P. Lachlan 10-6-73

Record 1975/39

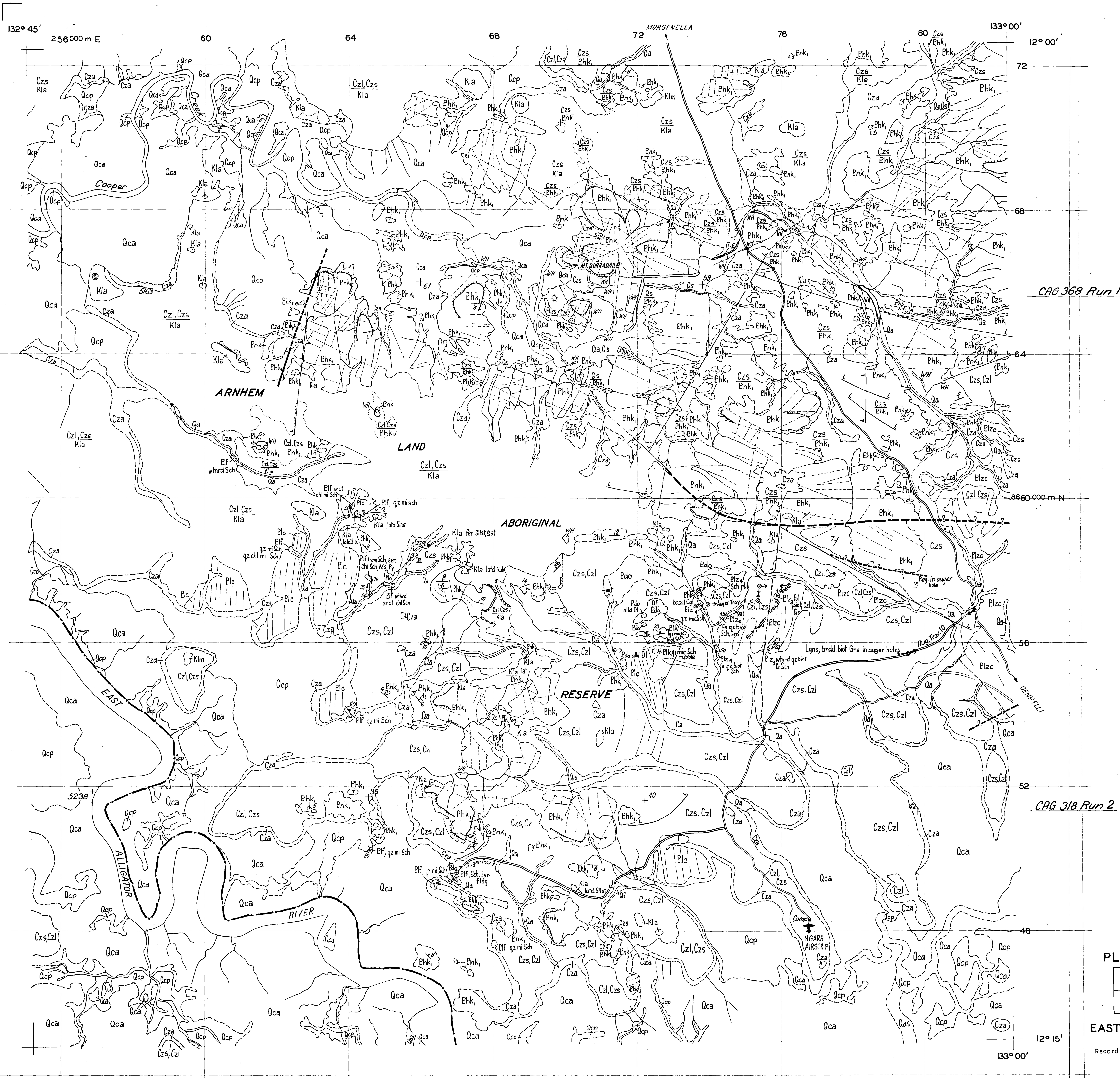


PLATE 6

EAST ALLIGATOR

1:50 000

Record 1975/39

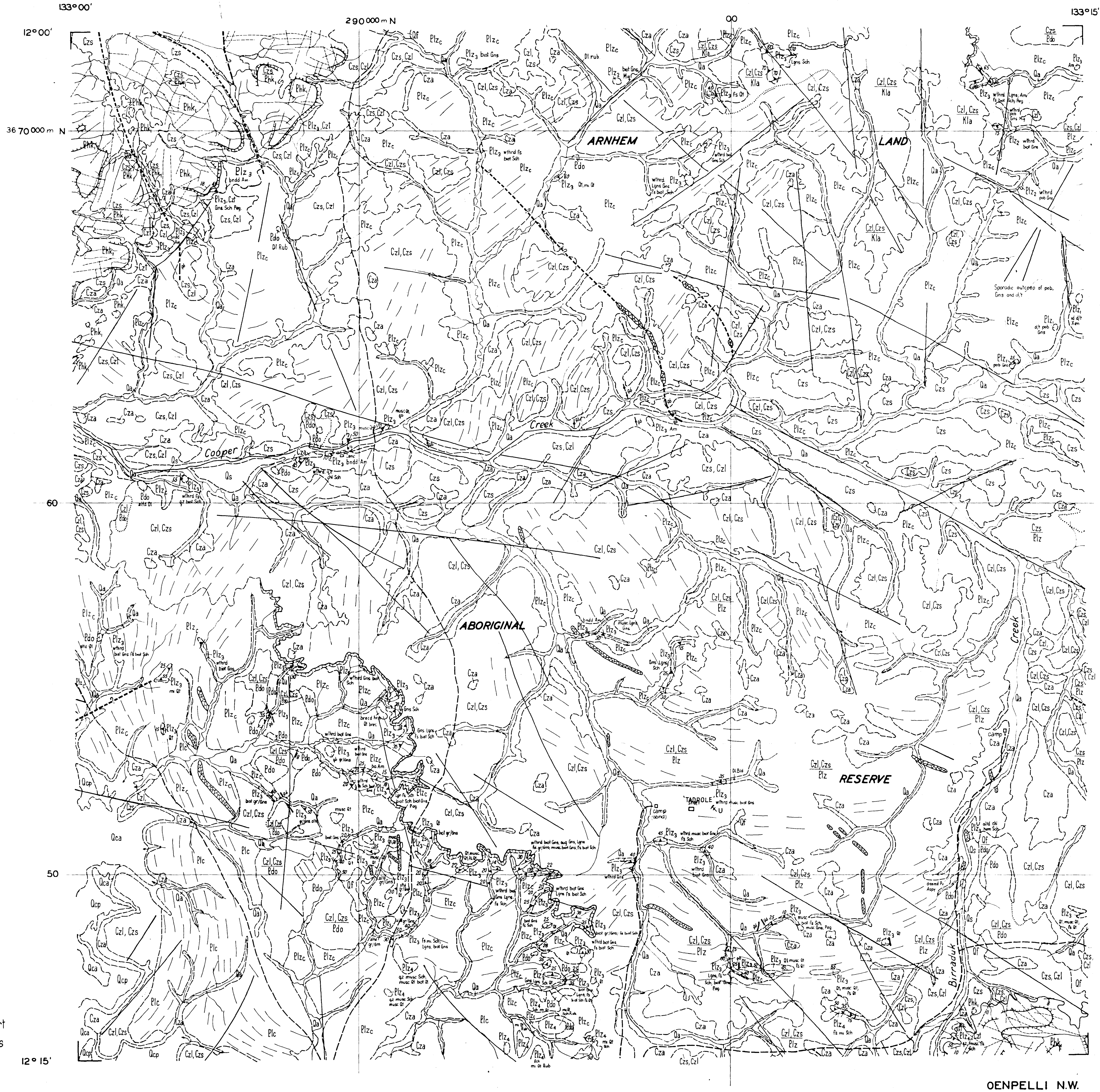
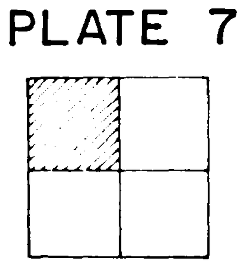


PLATE 7



OENPELLI
1:50 000

Geology: P.G. Smart

Compiled: P.H. Fuchs
31-5-74

Record 1975/39

OENPELLI N.W.

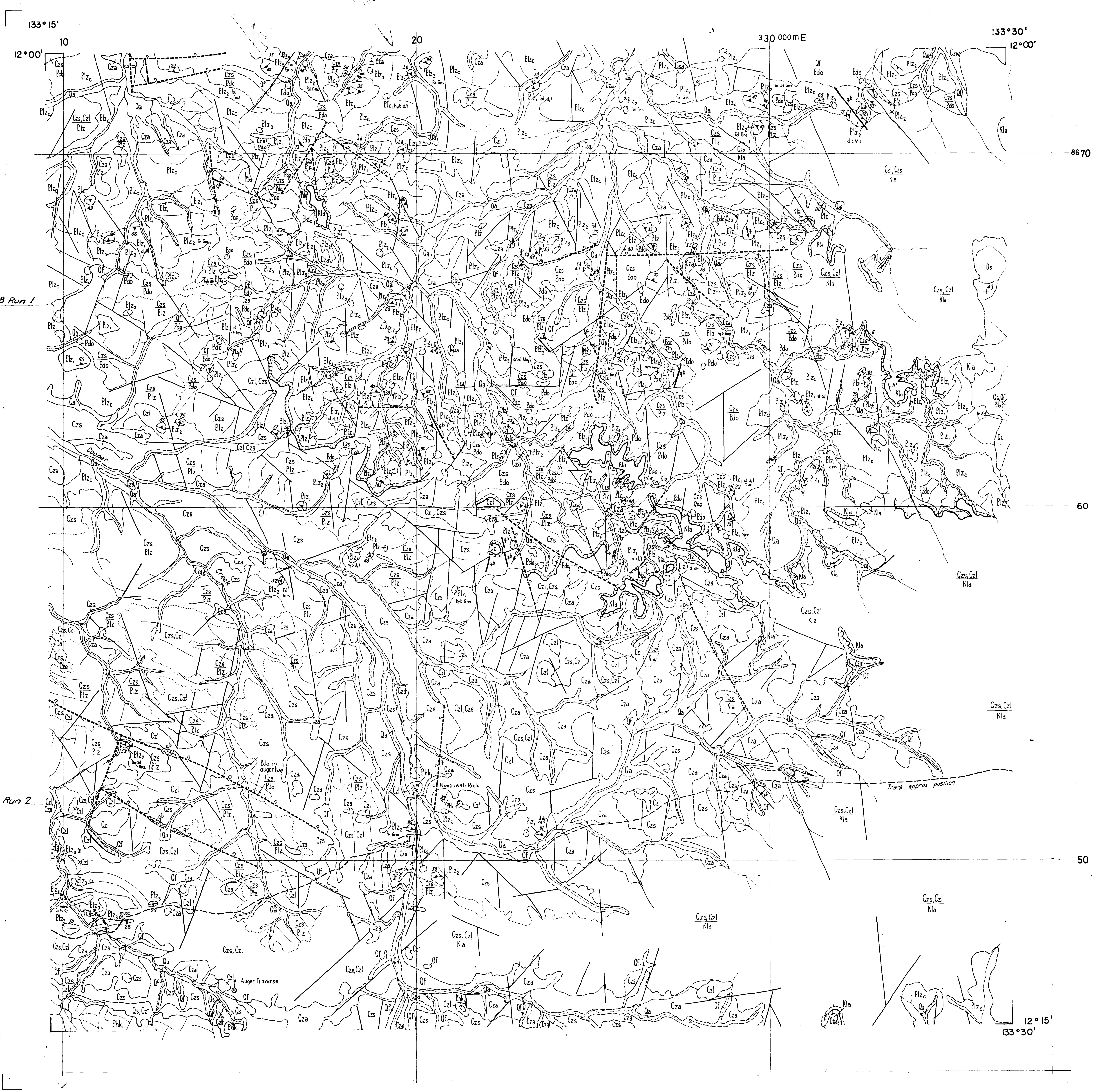


PLATE 8

OENPELLI
1:50 000

Geology: A.L. Watchman
Compiled: P.H. Fuchs
Feb 1974

Record 1975/39

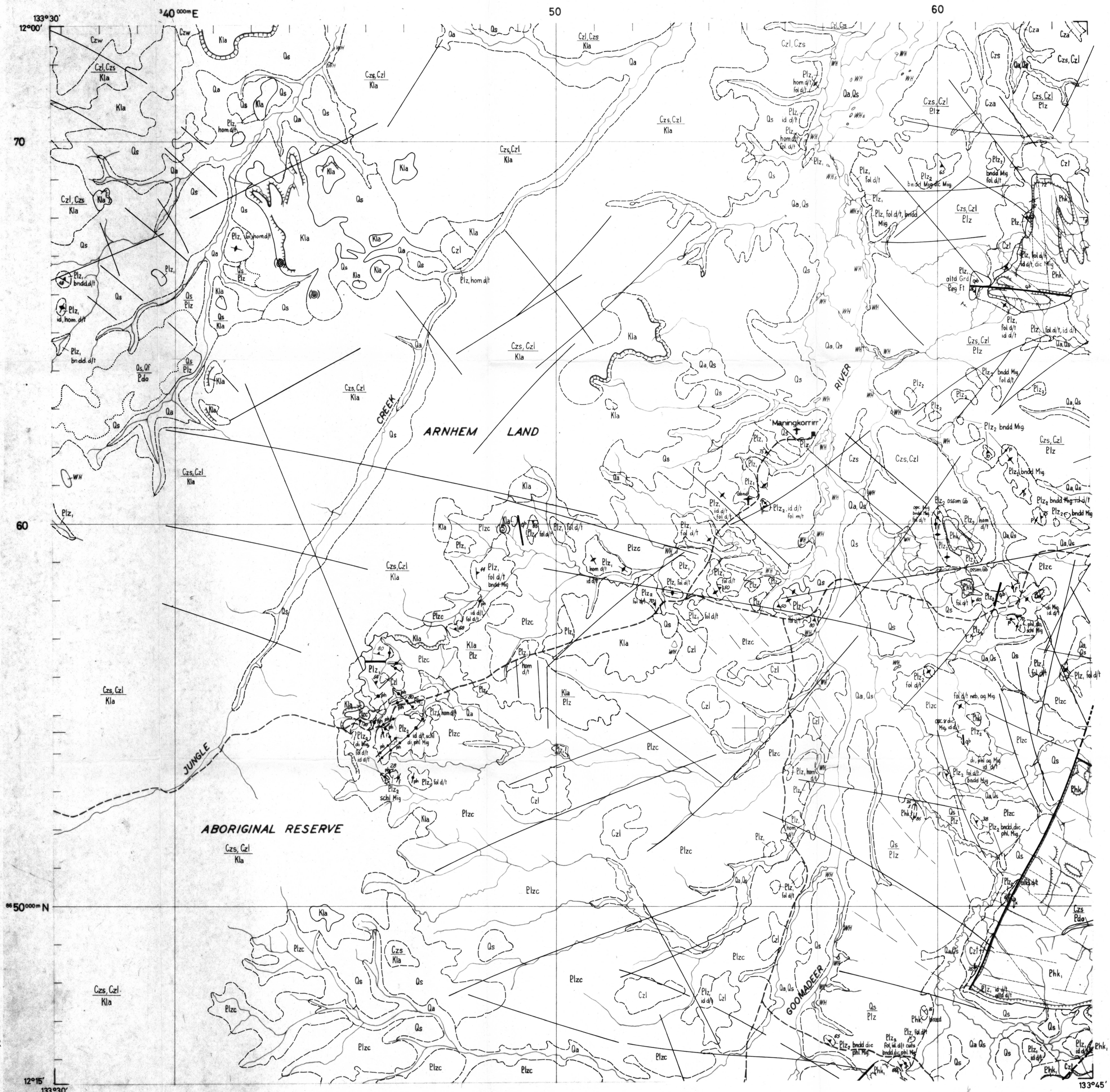


PLATE 9

GOOMADEER
1:50 000

Geology: R.S. Needham
Compiled: P.H. Fuchs
20-6-73

Record 1975/39

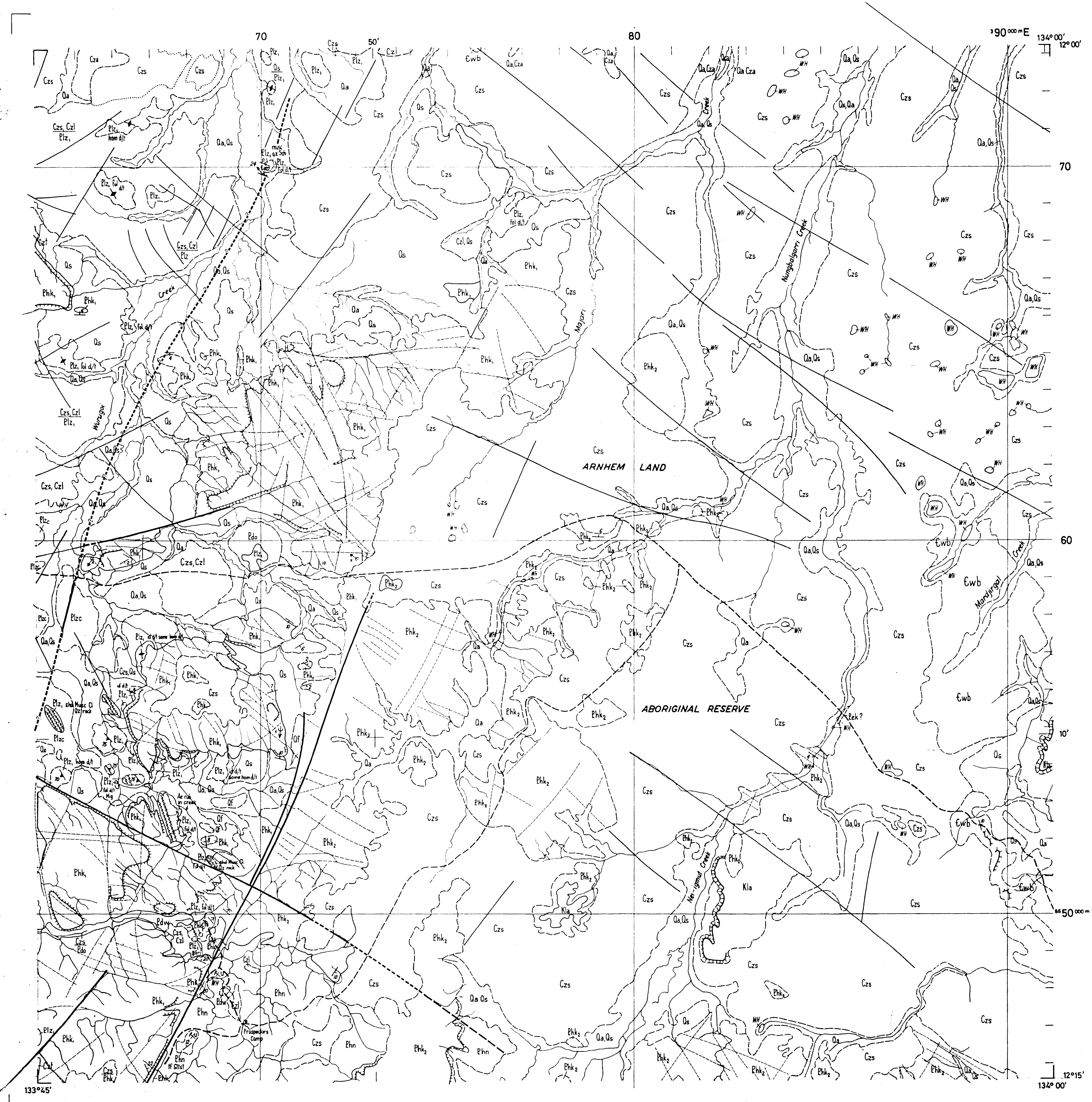


PLATE 10

GOOMADEER
1:50 000

Geology: R.S. Needham
Compiled: P.H. Fuchs, 5-12-73

Record 1975/39

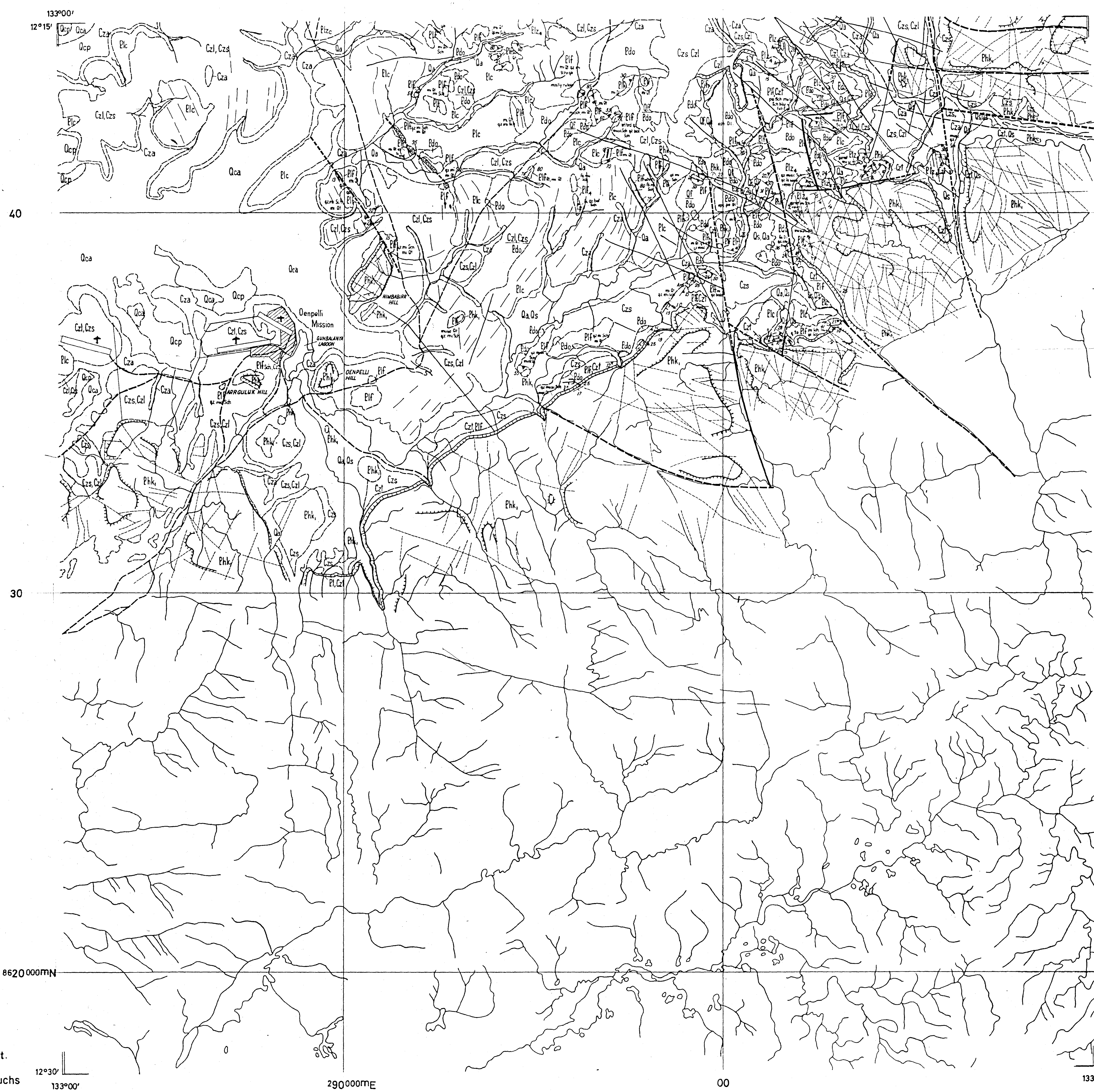


PLATE II

OENPELLI S.W.

1:50 000

GEOLOGY: P.G.Smart.

& R.S. Needham

COMPILED: P.H.Fuchs

Record 1975/39

PLATE 12

OENPELLI SE
1:50000
GEOLOGY: A L Watchman
COMPILED: P H Fuchs
Jan 1974

Record 1975/39

PLATE 13

GOOMADEER

1:50 000

Geology: R S Needham
Compiled: P.H. Fuchs
20-5-73

Record 1975/39

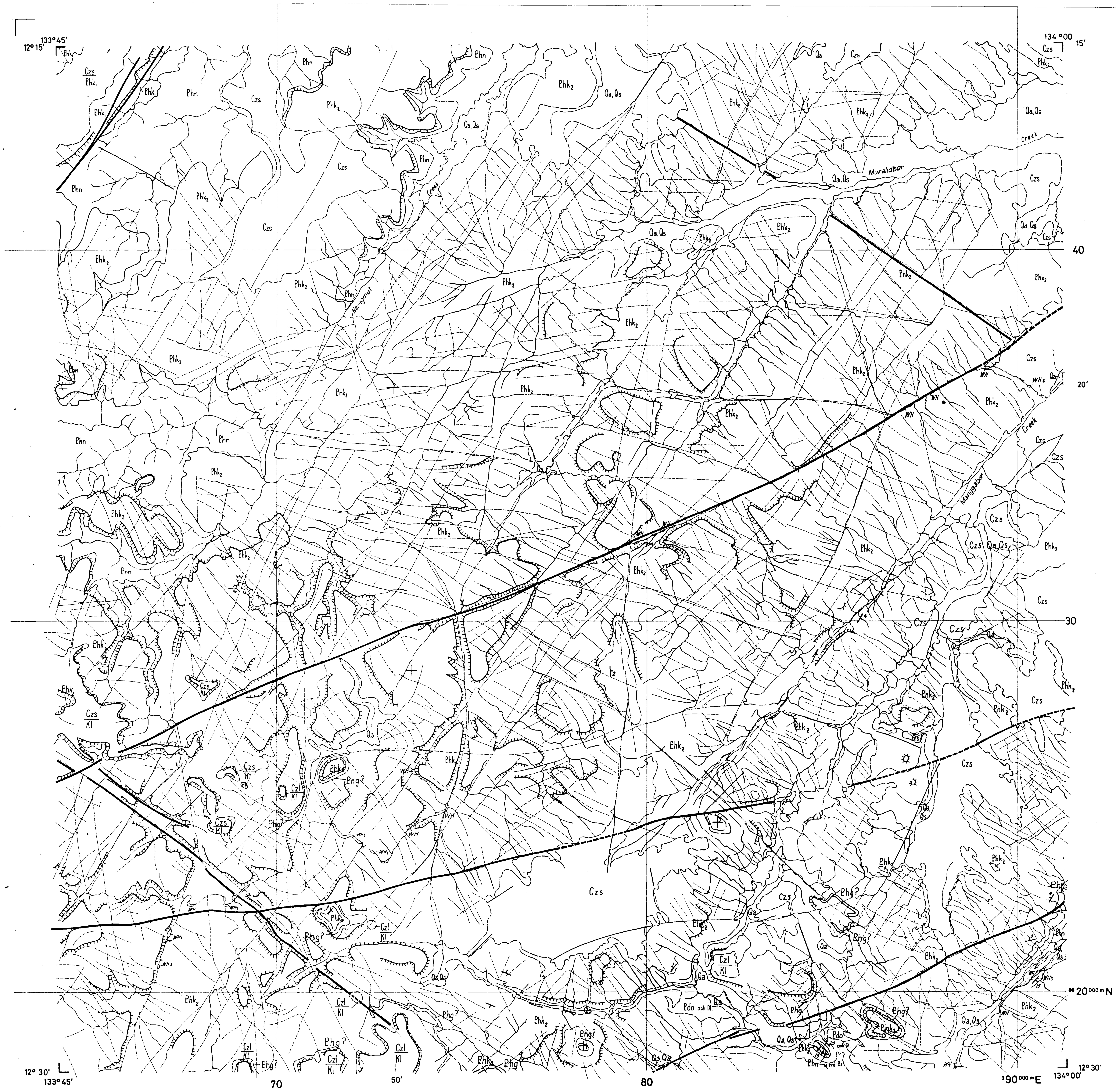


PLATE 14

GOOMADEER

1:50 000

Geology: R S Needham
Compiled P H Fuchs
5-12-73

Record 1975/39