COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT.
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

LUCAS, W.A.
4-MILE GEOLOGICAL SERIES

Sheet F/52-2, Australian National Grid.
EXPLANATORY NOTES No. 25.

Issued under the Authority of Senator the Hon. W. H. Spooner,
Minister for National Development.
1962.

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT.
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

LUCAS, W.A.
4-MILE GEOLOGICAL SERIES

Sheet F/52-2, Australian National Grid.
EXPLANATORY NOTES No. 25.

Issued under the Authority of Senator the Hon. W. H. Spooner, Minister for National Development.
1962.

DEPARTMENT OF NATIONAL DEVELOPMENT.

Minister: SENATOR THE HON. W. H. SPOONER, M.M.
Secretary: H. G. RAGGATT, C.B.E.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

Director: J. M. RAYNER.

These notes were prepared in the Geological Branch.
Chief Geologist: N. H. FISHER.

Explanatory Notes on the Lucas Geological Sheet

Compiled by *A. T. Wells*

INTRODUCTION.

The Lucas Sheet is bounded by latitudes 20°00' and 21°00' South and longitudes 127°30' and 129°00' East. It lies in the north-eastern section of the Great Sandy Desert and includes over 3,000 square miles of the Canning Basin. The only white people in the area live at the Balgo Mission, in the north-west corner. Scattered groups of nomadic aborigines wander over the area, but are mostly concentrated near the Mission station. The north-western part of the Sheet area is readily accessible, and there is a good road from Halls Creek to Balgo Mission, a distance of 168 miles. Access to the southern areas is limited to tracks from Balgo Mission through Gunnawarrawarra Rock Hole to Djaluwon Bore, and from Old Billiluna along the eastern shores of Gregory Salt Lake. The remainder of the area can be covered only by cross-country traversing.

It is essential for any party entering the area to carry supplies of water and food to last at least the duration of the traverse, as both surface water and native fauna are scarce. Rainfall is low, generally less than 10 inches per annum. Sporadic rock-holes and sand-soaks are the only sources of water supply in the more inaccessible parts, and cannot be relied upon.

History of Investigations

Before 1955 little geological exploration had been carried out on the Lucas Sheet area. The earliest investigations were by explorers in the late 19th and early 20th centuries.

A. C. Gregory (1857) was probably the first to enter the area; in 1856 he followed Sturt Creek southwards and discovered the salt lake into which the creek drains and which now bears his name. In 1873, Colonel Warburton (1875) travelled from Alice Springs to the Oakover River, but failed to find the salt lake discovered previously by Gregory. His exploration route passed through Lake Lucas towards the north-west, and he crossed the desert about 15 miles south of Gregory Salt Lake. In 1896, D. W. Carnegie crossed the area during his journey from the Western Australian Goldfields to Halls Creek and back (Carnegie, 1898).

Between 1898 and 1900, A. A. Davidson (1905) led a prospecting expedition for the Central Australian Exploration Syndicate Ltd, and investigated Precambrian rocks in the Lewis Range.

D. F. Mackay (1934) covered a great deal of the Canning Basin during an aerial survey expedition. One of the flights from Fitzroy Crossing crossed the Lewis Range, then turned due west to Gregory Salt Lake, and returned to Fitzroy Crossing. Air photographs were taken and a topographic map compiled from strip maps made during flights.

Maddox (1941) investigated small areas near Balgo Mission for Caltex (Aust.) Oil Development Pty Ltd. He correlated the rocks cropping out there with Permian sediments farther north-west and assigned the beds of the Kearney Range to the Proterozoic Era.

Evans (1948) gives a brief report on the stratigraphy and structure of some areas south of Balgo Mission.

Reeves (1949) carried out extensive aerial and ground geological surveys in the Canning Basin for the Vacuum Oil Company. Much of his report on the north-eastern area is based on work by Maddox and Evans. Reeves estimated that the Liveringa Formation near Balgo Mission is 500-600 feet thick and the shale and fossiliferous calcareous sandstone of the Noonkanbah Formation about 200 feet thick.

Terry (1957) gives a summary of investigation and exploration in the Canning Basin.

The area was photographed by the R.A.A.F. in 1953 from 25,000 feet, giving vertical coverage at a scale of approximately 1:50,000. Semi-controlled four-mile and one-mile photo-mosaics supplied by the National Mapping Division were used for the geological compilation.

In 1955 a geological party from the Bureau of Mineral Resources made geological traverses on the Lucas Sheet area using four-wheel-drive vehicles. Casey & Wells (1956) describe the travelling methods and conditions encountered during the reconnaissance. A surveyor from the Lands and Surveys Department, Perth, accompanied the party and took several astrofixes. Geologists from West Australian Petroleum Pty Ltd accompanied the Bureau party on several traverses and took gravity observations in the western part of the area. In 1956, a survey party from the Department of the Interior took several astrofixes and levels between Halls Creek and Balgo Mission; levelling only was carried out on the Lucas Sheet. The astrofix results shown in Table 1 were supplied by the State Lands and Surveys Department, Perth. In 1956, a party from the Bureau of Mineral Resources took gravity readings over the Sheet area, on a traverse between Balgo Mission and Lake Lucas.

TABLE 1 — *Astrofix Results for the Lucas Sheet.*

Station	Latitude	Longitude
N18	20°12'17.0"	128°40'00.0"
N14	20°31'13.0"	128°12'49.2"
N17	20°30'58.8"	128°55'02.4"
N28	20°57'47.28"	128°04'43.7"
N29	20°08'22.1"	127°48'14.7"

PHYSIOGRAPHY.

The two poorly marked physiographic divisions are the eastern area with dissected low-lying hills, and the western desert area or desert plateau with a characteristic breakaway (erosion scarp) topography. Their development has been controlled primarily by the geology : resistant Precambrian rocks underlie the eastern, and gently folded Palaeozoic and Mesozoic sediments the western part. The two divisions do not appear to be in any way delineated by differences in climate; the whole of the Sheet area is semi-arid.

The *Dissected Highland Area* is characterized by low rounded hills. Structural dip slopes are present in the Lewis Range, a long line of north-west-trending hills which have long westward slopes, and a breakaway scarp on the eastern margin. The Kearney and Phillipson Ranges are also composed of long strike ridges and hills of resistant silicified sandstone. Streams are limited to short channels that drain off hills on to the sand plan, proliferate, and disappear. Alluvial fans mark the debouchment of the small streams on to the plain. Aitchison Creek is the longest drainage channel in this area; it drains an area immediately to the north-east of the Lewis Range. Only a very short stream drains into the northern part of Lake White *, probably because of low rainfall and insufficient runoff from surrounding hills. The lake rarely contains any surface water, probably because drainage is to the south into an interconnected chain of salt lakes. Numerous small claypans surround the margin of Lake White, more especially to the north and north-west. A very large almost circular claypan lies about 15 miles north of the lake. The bed of the lake is composed of thin deposits of saline sand and clay overlying impervious calcareous sandstone and shale of the Lucas Beds.

Lake White probably has a structural origin It lies in a depression in the easily eroded Lucas Beds and has an elevation of about 1,040 feet, whereas the surrounding hills of resistant Precambrian rocks rise to about 1,250 feet above sea level. Upper Proterozoic rocks crop out about 20 miles from the lake margin. Two salt pans each about 2 miles long west of Lake White (one of which is officially named Lake Lucas) also have an impermeable bed composed of the Lucas Beds.

A large area of Quaternary caliche and travertine north-west of the Phillipson Range may delineate the bed of an ancient lake which has since dried up. This deposit is probably also in a structural basin in Upper Proterozoic rocks. Many streams from the surrounding hills drain into this depression; its elevation at the southern extremity is just over 1,100 feet.

The northern half of the Lucas Sheet area is devoid of sand dunes, whereas they are extremely abundant to the south. The rocks are less easily eroded, and the higher ranges in the north-east may have deflected the winds that are necessary for seif dune formation.

Desert Area : The western half of the Sheet is composed of low hills and breakaways, interspersed with sand-plain, with abundant seif dunes in the southern part. The area is underlain by Mesozoic and Palaeozoic sediments which are mostly easily eroded. The sediments are being most actively eroded in an area

---

* This lake was identified by the field party as the one named by Warburton Lake Lucas; but the Department of Lands & Surveys, Perth, has ruled that Lake Lucas is the claypan five miles west of this lake, which they say is either a northern arm of Lake White or is unnamed.

around Balgo Mission, where Derbai Creek and its many tributaries are down-cutting their courses. The creek eventually flows into Gregory Salt Lake, although its course is not well marked and in the extreme north-west corner disappears in an area of alluvial deposits. Salt Pan Creek and Djaluwon Creek have also dissected small areas of sediments and both eventually flow into Gregory Salt Lake. Pownall Creek and a small stream at Bishops Dell drain small areas in the Stretch Range and flow northwards on to the sand-plain, where they disappear in small alluvial flats or claypans. The drainage pattern is mostly dendritic, but is well developed only around Balgo Mission.

Most of the isolated rounded hills, pinnacles, and mesas and buttes of this division rise only 50-150 feet above the general level of the sand plain. A mesa and butte topography is well developed around Balgo Mission.

Part of Gregory Salt Lake lies in the north-west corner of the Sheet; it has no obvious relationship to geological structure. Sturt Creek is the major drainage channel draining into the northern end of the lake.

Development of Topography

The chief characteristics of the area are the intermittent rainfall and the internal drainage. Runoff is small and there are large daily ranges of temperature. The persistent internal drainage is responsible for local and temporary base levels which control the reduction of the upland areas.

The predominant land-forms in this area are : plains, including playas with alkali flats; bajadas; pediments; and structural plains. Structural plains are probably the most important. A few alluvial river flood-plains have formed. The bajadas are small and poorly developed; in most places the alluvial fans have not coalesced sufficiently to form true bajadas.

The area was probably uplifted evenly and the initial surface (Cotton, 1945) was probably a peneplain modified by the more prominent structural elements in the Palaeozoic and Mesozoic rocks and partly by the basement rocks in the east, which may be part of an exhumed Permian landscape. This peneplain was probably first lateritized and then broken down by desert weathering, with the production of breakaway scarps, and is now being reduced to a plain of arid erosion at a lower level. The basin sediments are being dissected in a large area in the north-west, but elsewhere the land-form has resulted from erosion of mountains rimmed by pediments which gradually coalesced to give a pediplain with residual hills. Pediments were later modified by deflation, and the material redistributed to form sand plains and seif dunes. Dunes grew in height and width largely through the action of cross-winds.

STRATIGRAPHY *

The Sheet includes a large area of Palaeozoic, Mesozoic, and Cainozoic deposits overlying a basement composed of Upper and Lower Proterozoic rocks. Basement rocks cropping out on the eastern half of the Sheet consist of Upper

---

* All numbers with prefix L (e.g. L44) marked on the Sheet refer to specimen localities. All specimens are housed in the Bureau of Mineral Resources Museum, Canberra.

Proterozoic sediments and Lower Proterozoic metamorphics and granite. The Upper Proterozoic rocks have been divided into Kearney Beds and Phillipson Beds on the basis of distribution, lithology, and structure, but they may prove to be co-eval. A synopsis of the stratigraphic succession is shown in Table 2. Selected rock specimens have been described by Lovering (1961).

Lower Proterozoic

The *Halls Creek Metamorphics* (Traves, 1955) crop out in the north-eastern corner of the Sheet area; they were not investigated on the ground, but mapped by photo-interpretation only. Intricate fold structures in these rocks do not appear to have any preferred orientation.

The *Lewis Granite* (Casey & Wells, 1961) crops out in scattered areas, chiefly in the north-eastern quadrant. The largest outcrops are on the eastern margin of the Lewis Range, where the rock type varies from a red granite to a muscovite granodiorite, both with pegmatite and quartz dykes. Granite crops out at the base of Mount Hughes beneath the Phillipson Beds and west of the Kearney Range at L42, and is undoubtedly present beneath the sand-plains between Mount Hughes and the Kearney Range: several outcrops of granite have been photo-interpreted in these areas. Between the Lewis and Kearney Ranges the granite may be overlain by Upper Proterozoic rocks.

Upper Proterozoic

The type area for the *Kearney Beds* (Casey & Wells, 1961) is in the north-west-trending Kearney Range about 20 miles east of Balgo Mission. The beds dip steeply, mostly to the north-east, and in the Kearney Range probably unconformably overlie the Lower Proterozoic Lewis Granite. The Phillipson Beds also unconformably overlie the Lewis Granite, in the Lewis Range, and the two sequences may therefore prove to be co-eval. At the southern end of the Kearney Range quartz veins and joints are common and some thin beds of conglomerate are present.

The *Phillipson Beds* (Casey & Wells, 1961) are confined to the eastern half of the Sheet area, where they crop out as long ranges composed of strike ridges, the most important of which are the Phillipson and Lewis Ranges. Mount Hughes is a prominent feature near the centre of the Sheet. In the Lewis Range and at Mount Hughes the Phillipson Beds are only about 20 feet thick and form a thin veneer over the Lewis Granite. The basal parts of these sections are composed of a very coarse admixture of weathered products of granite, including angular quartz, feldspar, and muscovite. Above this basal section the sandstone is coarse-grained and current-bedded. A conglomerate possibly of comparable age crops out at L14 (Phillipson Range); it contains subangular and angular chert and jasper fragments. Interference, wave, and current ripple marks are common in the sandstones in the Phillipson Range and at L15.

Scattered boulders of grey-brown sandstone and limestone about $\frac{1}{2}$ mile east of Yam Hill are either Upper Proterozoic or part of a sequence in the Lucas Beds. The sandstone is grey-brown, medium-grained, partially silicified, and commonly covered with pisolitic ironstone. The limestone is massive, the coarser-grained varieties being dark grey and the finer-grained varieties flesh-coloured. Some of the limestone may be dolomitic, and is possibly the same age as the Upper Proterozoic dolomites found farther south at Red Cliff Pound on the Stansmore Sheet.

PALAEOZOIC — UNDIFFERENTIATED

The *Lucas Beds* (Casey & Wells, 1961) consist of interbedded laminated claystone and calcareous sandstone showing lustre mottling. At Yam Hill, soft, purple-brown, medium and fine-grained friable sandstone of the Lucas Beds is overlain by about 30 feet of siliceous, massive, current-ripple-marked medium and fine-grained sandstone with some interbedded fine white or yellow-brown siltstone. The upper part of the section has lithological affinities with Permian sediments of the Canning Basin. Contacts of the Lucas Beds with doubtful Upper Proterozoic rocks occur about half a mile east of Yam Hill (L48) and about 3 miles north of L21.

The Lucas Beds do not show any notable structural deformation; they dip only 3° to the east. Strike lines, joints, and small dip faults are visible on the bed of Lake White and are a reflection of the interbedded fontainebleau sandstone and fine shale.

The Lucas Beds appear to have been deposited in a structural basin surrounded by hills of Upper Proterozoic rocks. The age of the beds is unknown and they have no lithological affinities with other sediments of the Canning Basin. They may represent the westward extension of Palaeozoic rocks from the Northern Territory. A similarity between the Lucas Beds and sediments probably of the Noonkanbah Formation cropping out on the northern part of the Helena Sheet (F/52-5) was noted by Veevers in 1957 (J. J. Veevers, pers. comm.). These rocks also occur below Recent deposits in a small claypan and have a very similar photo-pattern to the Lucas Beds on the bed of Lake White.

UPPER DEVONIAN OR LOWER CARBONIFEROUS

Probable Upper Devonian or Lower Carboniferous rocks crop out in the Kearney Range at L41, in a downfaulted trough between rocks of the Kearney Beds. *Leptophloeum* cf. *L. australe* (McCoy) has been identified by Brunnschweiler & Dickins (1954) from a specimen collected by Reeves (1949) near the Kearney Range, possibly from the outcrops at L41. This plant is widely distributed in Upper Devonian rocks in Australia. The rocks at L41 are medium-grained white sandstone, cross-bedded, with occasional pebbles of quartzite. At L40 rocks of similar lithology contain pebbles of pink claystone up to 3 inches across.

PERMIAN

The Permian formations can be identified with those of the Fitzroy Basin, except that the Poole Sandstone cannot be differentiated in this part of the basin. The Liveringa Formation has been divided into three members, but the upper marine Hardman Member does not crop out in this Sheet area. Plant fossils from the Permian formations have been described by White (1957) and marine fossils by Dickins (1958).

The *Grant Formation* (Guppy et al., 1958) occupies a very small area in the northern part of the Sheet, where it is overlain by the Noonkanbah Formation. The formation has been mapped by the continuation of a similar photo-pattern of outcrops on the Billiluna and Mount Bannerman Sheets. At L39 the rock is coarsely cross-bedded, medium-grained sandstone with some coarser beds. The beds contain many clay pellets, wood remains, and mica. No sediments referable to the Grant Formation were found south of the Kearney Range, and younger Permian formations appear to transgress the Grant Formation and directly overlie the Precambrian basement rocks.

The *Noonkanbah Formation* (Guppy et al., 1958) covers comparatively small areas and outcrops are generally poor. The soft shale and fine quartz greywacke form open plains strewn with small fragments but very little solid outcrop. The dome structure east of Balgo Mission is composed of shale and some coquinite beds of the Noonkanbah Formation. A large plain near Thomas Peak is underlain by the Noonkanbah Formation and remnants of the Balgo and Condren Sandstone Members. No unconformities were seen between the Noonkanbah Formation and the overlying Members.

In all sections measured during traverses the Balgo Member was not proved to be missing between the Noonkanbah Formation and the Condren Sandstone Member, and no surfaces of unconformity were seen. Photo-interpretation in other areas does not show enough detail to be certain that the Balgo Member is absent from the succession, except in the Kearney Range, where the Balgo Member appears to have been overlapped by the Condren Sandstone Member.

Two members of the *Liveringa Formation* crop out on this Sheet, the lower, marine, fossiliferous Balgo Member and the upper, plant-bearing, Condren Sandstone Member.

The *Balgo Member* (Casey & Wells, 1961) crops out at many localities on the western half of the Lucas Sheet area and in some places forms small breakaway scarps, the beds being more resistant than the underlying Noonkanbah Formation. Good exposures of the Member are present in the large area of dissected sediments around Balgo Mission. Outcrops at Gumbo Point and south of Dooma-Dora are breakaways in Balgo Member 200 feet high, capped by the Condren Sandstone Member, and with the Noonkanbah Formation cropping out on the flats. The outcrops of the Balgo Member are not sufficiently wide to show accurately at four-mile scale, but the outcrop width has been exaggerated slightly on the map at these localities so as to show them.

North of Gunnawarrawarra Rock Hole trend lines are easily visible on flat plains where the Balgo Member crops out, but are not visible in the overlying Condren Sandstone Member. This is because the massive resistant jointed Condren Sandstone Member crops out in dissected breakaways and in this type of outcrop any dips and trend-lines are not easily visible.

The *Condren Sandstone Member* (Casey & Wells, 1961) covers the largest total area of any of the Palaeozoic or Mesozoic formations. It is named from the type locality at Condren Pinnacles in the north-west corner of the Sheet area. The sediments are resistant to erosion and form mesas, buttes, and isolated pinnacles. The sandstone has a well developed joint pattern and in many sections contains pebble beds and lenses. At Condren Pinnacles claystone and sandstone are rhythmically bedded. The plant remains occur in a white, friable, medium-grained sandstone which contains some micaceous and clay beds. The Condren Sandstone Member here overlies the Balgo Member with no noticeable unconformity. At Gordon Hills a medium-grained cross-bedded sandstone is the predominant rock, with plant fossils occurring in thin limonitic beds.

Triassic

Beds correlated with the *Blina Shale* of the Fitzroy Basin crop out in the Stretch Range, where they overlie the Condren Sandstone Member with a probable disconformity. The rock is predominantly thin-bedded shale, with remains of *Isaura*. No details of sections are available and other outcrops in the south-eastern Stretch Range have been photo-interpreted.

Quaternary

Quaternary deposits are widespread, the most common being wind-blown sand. The sand is red or orange, and is heaped into seif dunes, which are abundant on the southern half of the Sheet area. Alluvial deposits are restricted to small areas of outwash plain, where short streams drain on to the sand-plain, and to clay deposits in small claypans. Black-soil deposits chiefly overlie formations containing soft shale or claystone and are probably residual. Thin deposits of salt occur on Lake Lucas; and some are scattered over Gregory Salt Lake, but alluvial deposits are more common there. Caliche and travertine are widespread, the most noticeable occurrences being between the Lewis Range and the Kearney Range, and north of Lake Lucas. The large caliche deposits have been formed by internal drainage into the low-lying area between the Lewis and Kearney Ranges. The caliche is soft and powdery, whereas the travertine north of Lake Lucas is indurated and contains a good deal of chalcedony. Similar travertine deposits occur in the low-lying areas between the Gordon Hills and the Stretch Range.

STRUCTURE

The major structural units present on the Lucas Sheet area are the intracratonic Canning Basin, the smaller sedimentary basin containing the Lucas Beds, and the basement, cropping out in the structural highlands and forming the floor of the basins.

The sediments of the Canning Basin occupy the western half of the Sheet and are sub-horizontal except near large faults, where dips up to 35° are present. Faults in the Permian and Mesozoic sediments trend north-west, but their displacement is not known. Stratigraphic displacements on some of the faults indicate throws of 200 feet or less; some of the fault planes dip at steep angles to the west.

The prominent fault-pattern trending in a north-westerly direction through the Stretch Range may delineate the boundary between shelf-type sedimentation to the east and trough sedimentation to the west : this distinct line of faulting may be the surface trace of the edge of a basement ridge. It continues to the north-west through the Cornish and Mount Bannerman Sheets and to the south forms the eastern scarp of the Stansmore Range on the Stansmore Sheet area. The thickness of sediments in the Stansmore Range has been calculated to be 7,800 feet from gravity data (Garrett, 1956). A similar thickness of sediments may be present to the west of the fault in the Stretch Range, but there is no large gravity gradient parallel to the fault.

The large negative gravity anomaly trending northwards from the Stansmore Range follows the faulted north-plunging anticline trending north from the Gordon Hills and the area between the Kearney Range and the Permian sediments to the west. This area is also marked by a faulted zone, the faults being parallel to the basin margin. The gravity gradient in this area indicates that the sediments thicken fairly rapidly to the west. A positive gravity anomaly near Gregory Salt Lake may indicate that the basement rocks are comparatively shallow there.

The Lucas Beds in the small sedimentary basin at the south-easterly corner of the Lucas Sheet show a persistent easterly dip of about 3°. Only small dip faults with small displacements cut these rocks. The basin is rimmed by Upper Proterozoic rocks; but it may have been connected with the Canning Basin, at least in Permian times, as an outcrop of possibly Permian sediments is present at Yam Hill.

Rocks similar to those forming the basement to the sedimentary basins crop out on the eastern half of the Lucas Sheet area. The Lower Proterozoic metamorphics show the greatest deformation, with intricate closed fold-structures. The metamorphics have been intruded by post-tectonic plutons of granite. The Upper Proterozoic rocks show less intense open folding, with the steepest dips in the Kearney Beds in the Kearney Range. No contact of the Upper Proterozoic rocks with the metamorphics was seen, but the unconformable contact with the Lewis Granite is well exposed in the Lewis Range and at Mount Hughes. The surface of unconformity in the Lewis Range is a well developed flat plane dipping to the east at about 4°. Generally the fold structures and trends in the Upper Proterozoic rocks are broadly parallel to the Canning Basin margin.

ECONOMIC GEOLOGY

Water

There is little demand for underground water except in the area near the Balgo Mission, where water is present in the Permian sediments at depths ranging from 30 to 50 feet, but is generally saline or alkaline. The wells at Balgo Mission and Dooma Dora both produce water with a high content of salts. New bore sites in the probable Upper Devonian or Lower Carboniferous sediments were selected near the Kearney Range, where it is hoped to strike good water in the estuarine or shallow water sediments, above the saline water occurring in the Permian rocks. In the desert area to the south and south-east good water should be available in areas of both Permian and Upper Proterozoic rocks at about 40 feet. Good water occurs in the Permian Balgo Member at old Billiluna Station.

Evaporites

Only thin deposits of evaporites occur on Lake Lucas and Gregory Salt Lake, and they have no commercial significance.

Petroleum

The Permian and Mesozoic rocks include source and reservoir rocks, but only the shale beds in the Noonkanbah Formation and possibly the Balgo Member are good cap rocks. However, it is more likely that petroleum accumulations would occur in the older Palaeozoic rocks, if there are suitable cap rocks. Gravity information suggests that the Canning Basin on this Sheet area includes both shelf and trough sedimentation. The hinge-line of these two areas is probably represented by the faulted zone through the Stretch Range : a shelf lies to the east of this zone and a trough to the west, and the fundamental control may be a subsurface basement ridge, with the sediments more intensely folded and faulted in the trough area. The shelf is likely to contain shallow-water sandstone and quartz greywacke and the trough shale and deeper water equivalents. The best source rocks are probably the deeper water equivalents of the Ordovician sandstones that crop out at the margin of the basin farther north (Ordovician source beds containing traces of petroleum crop out at Prices Creek in the Fitzroy Basin). The easternmost extension of known Devonian rocks is near Kai Ki yard on the northern margin of the Mount Bannerman Sheet, and possible Upper Devonian or Lower Carboniferous rocks crop out in the Kearney Range. The hinge-line area of sedimentation mentioned above may include closed anticlines, and Devonian and Ordovician organic reefs may have developed along it.

The gravity results show a sharp gradient on the western margin of the Kearney Range, extending south through Gordon Hills, which may indicate deeper basement with a small subsidiary trough to the west of this line of faulting.

The future appraisal of petroleum potentialities depends on the precise determination of the subsurface configuration of the basement rocks and the distribution of any pre-Permian rocks, particularly the Ordovician and Devonian sediments.

Two anticlinal structures — a dome in outcropping Noonkanbah Formation six miles east of Balgo Mission and a north-south anticline in outcropping Balgo and Condren Members 24 miles south-south-east of Balgo Mission — offer structural traps in the Permian sediments, but would probably not contain sufficient source rocks.

BIBLIOGRAPHY.

BRUNNSCHWEILER, R. O., and DICKINS, J. M., 1954 — Pre-Permian, probably Devonian plants from near Gregory's Salt Sea, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1954/27 (unpubl.).

CARNEGIE, D. W. 1898 — SPINIFEX AND SAND. London, Pearson.

CASEY, J. N., and WELLS, A. T., 1956 — Operational problems and conditions in the North-East Canning Basin, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1956/93 (unpubl.).

————————————, 1961 — The regional geology of the North-Eastern Canning Basin, Western Australia. *Bur. Min. Resour. Aust. Rep.* 49.

COTTON, C. A., 1945 — GEOMORPHOLOGY. An introduction to the Study of Landforms. Christchurch, Whitcombe and Toms.

DAVIDSON, A. A., 1905 — Journal of explorations in Central Australia, 1898 to 1900. *S. Aust. parl. Pap.* 27.

DICKINS, J. M., 1958 — Permian fossils from the Canning Basin, Western Australia. *Bur. Min. Resour. Aust. Rec.* 1958/7 (unpubl.).

EVANS, H. J., 1948 — Memorandum on geological reconnaissance south and south-west of Pallotine Mission. *Unpubl. Rep. for Frome-Broken Hill Co. Pty Ltd,* 2000-G-20.

GARRETT, M. J., 1956 — Gravity traverses by geological party G. C. in the eastern portion of the Fitzroy - Canning Basin. *Unpubl. Rep. for W. Aust. Petrol. Pty Ltd.*

GREGORY, A. C., 1857 — Papers relating to an expedition recently undertaken for the purpose of exploring the Northern portion of Australia. *Brit. parl. Pap., London.*

GUPPY, D. J., LINDNER, A. W., RATTIGAN, J. H., and CASEY, J. N., 1958 — Geology of the Fitzroy Basin, Western Australia. *Bur. Min. Resour. Aust. Bull.* 36.

LOVERING, J. K., 1961 — Petrographic description of selected rock specimens from the Canning Basin, Western Australia. Appendix B. in *Bur. Min. Resour. Aust. Rep.* 49 (1961) by Casey, J. N., and Wells, A. T.

MADDOX, W. H., 1941 — A geological reconnaissance of the north-eastern part of the Fitzroy Basin, Western Australia. *Unpubl. report for Caltex (Aust.) Oil Development Pty Ltd.*

MACKAY, D. F., 1934 — The Mackay Aerial Survey Expedition, Central Australia, May-June 1939. *Geogr. J.*, 84(6) Dec. 1934.

REEVES, F., 1949 — Geology and oil prospects of the Desert Basin Western Australia. *Unpubl. report for Vacuum Oil Co. Pty Ltd.*

TERRY, M., 1957 — The Canning Basin of Western Australia. *Geogr. J.*, 123(2) 157-166, June 1957.

TRAVES, D. M. 1955 — The geology of the Ord-Victoria Region, Northern Australia. *Bur. Min. Resour. Aust. Bull.* 27.

TRAVES, D. M., CASEY, J. N., and WELLS, A. T., 1956 — The geology of the south-western Canning Basin, Western Australia. *Bur. Min. Resour. Aust. Rep.* 29.

VEEVERS, J. J., 1957 — Operations of the 1957 Canning Basin Party. *Bur. Min. Resour. Aust. Rec.* 1957/90. (unpubl.).

VEEVERS, J. J., and WELLS, A. T., 1961 — The geology of the Canning Basin, Western Australia. *Bur. Min. Resour. Aust. Bull.* 60.

WARBURTON, P. E., 1875 — A journey across the western interior of Australia. *S. Aust. parl. Pap.* 28.

WHITE, Mary E., 1957 — Report on plant fossils from the north-east Canning Basin, W.A. *Bur. Min. Resour. Aust. Rec.* 1957/74 (unpubl.).

TABLE 2. — STRATIGRAPHY OF THE LUCAS SHEET.

Age	Map Symbol	Formation	Thickness (in feet)	Lithology	Fossils	Economic Geology	Time equivalent
QUATERNARY	Qb	Black Soil	10 +	Black clay soil	—	—	
	Qa	Alluvium	20 ±	Alluvial soil, sand & gravel	—	Water	
	Qs	Sand	0-120 ±	Hematite-stained medium to fine-grained quartz sand	—	Water	
	Q1	Travertine	20 +	Hard marl & limestone with varying amounts of calcedony	—	Limestone	
	Qc	Caliche	10 +	Soft calcareous material	—	—	
	Qt	Evaporites	1 +	Salt & other evaporites	—	—	
TRIASSIC	Rb	Blina Shale	100 +	Micaceous thin-bedded shale	*Isaura*	—	Blina Shale of Fitzroy Basin
		DISCONFORMITY					
PERMIAN	Pr	Condren Sandstone Member (Liveringa Formation)	200 +	Sandstone, shale & thin beds of fine conglomerate	Fossil plants	Water	Upper plant-bearing beds of Liveringa Formation - Fitzroy Basin
	Po	Balgo Member (Liveringa Formation)	70 +	Sandstone, shale, & quartz greywacke	Marine macro-fossils	—	Lightjack Member of Fitzroy Basin
	Pn	Noonkanbah Formation	200 ±	Shale & fine sandstone	Marine macro-fossils	—	Noonkanbah Formation of Fitz-roy Basin
	Pg	Grant Formation	200 ±	Poorly sorted coarse to medium-grained sandstone with pebbles & some mica	Fossil plants	Water	Grant Formation of Fitzroy Basin
UPPER DEVONIAN LOWER CARBONIFEROUS	D-C	Not named	100 +	Medium - grained cross - bedded sandstone, occasional pebbles of quartzite and claystone	Fossil plants	Water	? Part equivalent of Laurel Formation of Fitzroy Basin
UNDIFFERENTIATED PALAEOZOIC	Pzl	Lucas Beds	100 +	Fontainebleau sandstone and interbedded laminated clay-stone	—	—	? Extension of Lower Palaeo-zoic rocks from Northern Territory
		UNCONFORMITY					
UPPER PROTEROZOIC	Bul	Phillipson Beds	200 +	Current-bedded sandstone with some pebbles & a basal conglomerate	—	Water	Part equivalent of Kimberley Plateau Succession & Upper Proterozoic Sequence of S. W. Canning Basin. (Traves, Casey, & Wells, 1956).
	Bun	Kearney Beds	2,000 ±	Silicified sandstone	—	—	'Nullagine Series' of Pilbara Block
		UNCONFORMITY					
LOWER PROTEROZOIC	Plw	Lewis Granite	—	Granite & muscovite grano-diorite with pegmatite & quartz veins	—		Granite of Lamboo Complex
	Plh	Halls Creek Metamorphics	—	Photointerpreted — probably quartz greywacke, slate, lamin-ated claystone, as on Billiluna Sheet.	—	Traces of gold & possibility of other metallic deposits.	Probably Lower Proterozoic Metamorphics of the South-Western Canning Basin (Traves, Casey, & Wells, 1956)

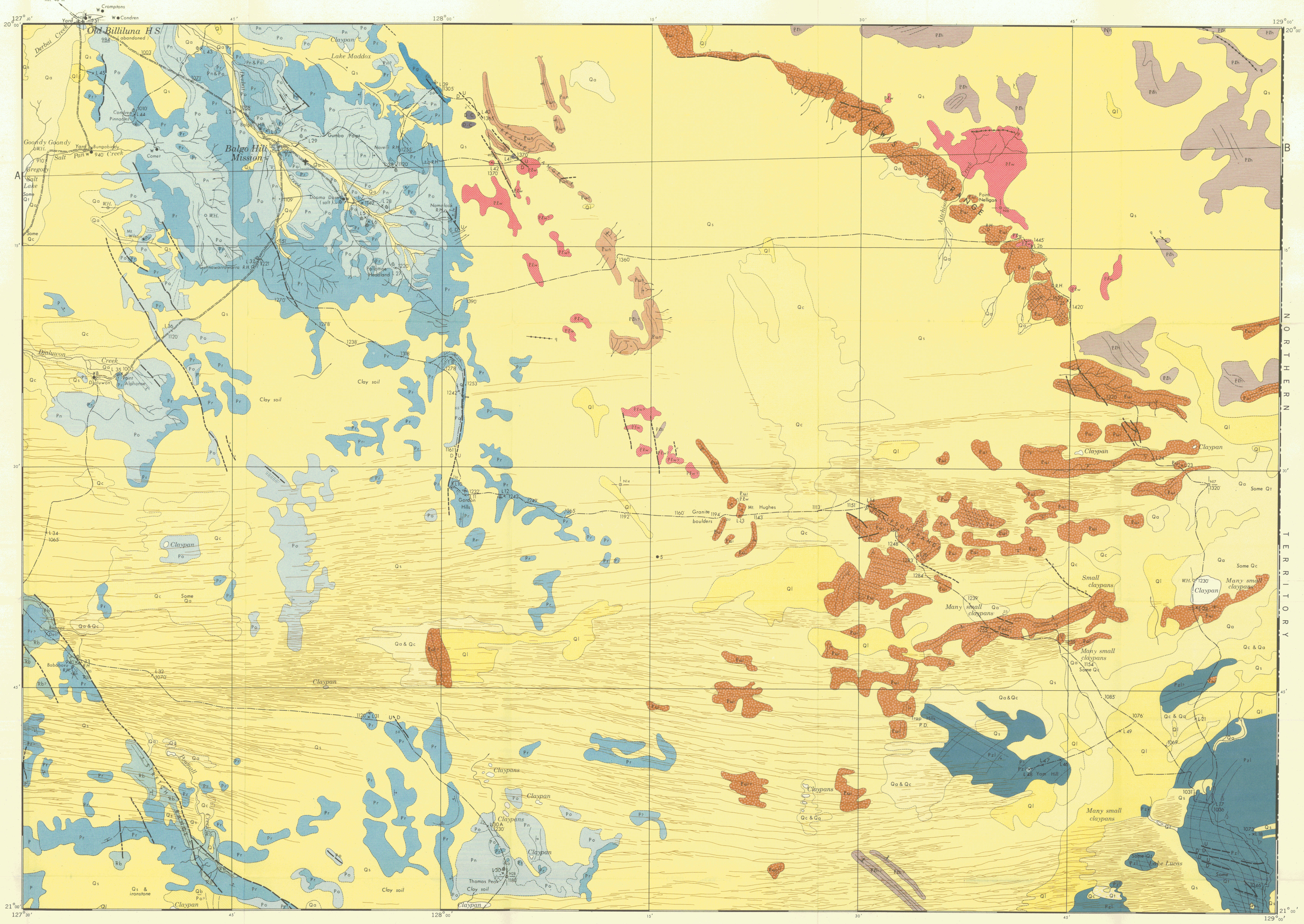
FIRST EDITION 1960

AUSTRALIA 1:253,440

LUCAS

WESTERN AUSTRALIA

4 MILE GEOLOGICAL SERIES SHEET F 52-2



Reference

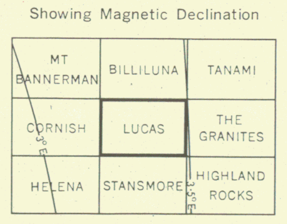
CAINOZOIC	QUATERNARY		Qb	Black or clay soil
			Qa	Alluvium
			Qs	Sand
			Ql	Hard travertine, tufa
			Qc	Caliche or travertine powder
			Qt	Evaporites
MESOZOIC	TRIASSIC	Blina Shale	Rb	Shale and fine sandstone
		Disconformity		
PALAEOZOIC	PERMIAN	Liveringa Formation: Condren Sandstone Member	Pr	Sandstone, fine conglomerate and shale
		Liveringa Formation: Balgo Member	Po	Sandstone, shale and quartz greywacke
		Noonkanbah Formation	Pn	Fine sandstone and shale
		Grant Formation	Pg	Poorly sorted sandstone with pebbles
		Undifferentiated	P	Sandstone and shale
	U.DEVONIAN — L.CARBONIFEROUS ?		D-C	Sandstone with some pebbles
	UNDIFFERENTIATED	Lucas Beds	Pzl	Calcareous sandstone with interbedded laminated claystone
		Unconformity		
PROTEROZOIC	UPPER	Phillipson Beds	Pui	Current-bedded sandstone and basal conglomerate
		Kearney Beds	Pun	Silicified sandstone
			Pu	Undifferentiated sediments (in section only)
		Unconformity		
	LOWER	Lewis Granite	Plw	Granite and muscovite granodiorite
		Halls Creek Metamorphics	Plh	Quartz greywacke, slate, and laminated claystone

- Established geological boundary, position approximate
- Inferred boundary
- Established fault, position approximate, relative movement and dip indicated where known
- Established fault, concealed.
- Inferred fault, concealed.
- Strike and dip of strata
- Horizontal strata
- Dip < 15° (air-photo interpretation)
- Dip 15°-45° (air-photo interpretation)
- Dip > 45° (air-photo interpretation)
- Trend of bedding (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Dyke: q - quartz; p - pegmatite
- Marine macrofossil locality
- Plant fossil locality
- ×L12 Text reference to specimen locality
- Route of geological party's traverse
- Geological party's traverse along vehicle track
- Sand dunes
- Windpump
- B Bore
- W Well
- W.H. Waterhole
- R.H. Rockhole
- S Spring or soak
- Fence
- State boundary
- Landing ground
- 980' Height in feet, instrument levelled (datum: mean sea level Derby)
- 969' Height in feet, barometric (datum: mean sea level Derby)
- N17 Astro station
- P.D. Position doubtful

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.
Transverse Mercator Projection.

INDEX TO ADJOINING SHEETS

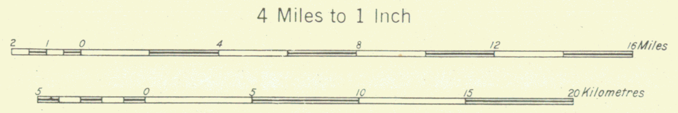
Showing Magnetic Declination



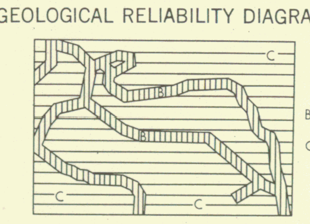
ANNUAL CHANGE 0' 30"E

Scale

4 Miles to 1 Inch



GEOLOGICAL RELIABILITY DIAGRAM

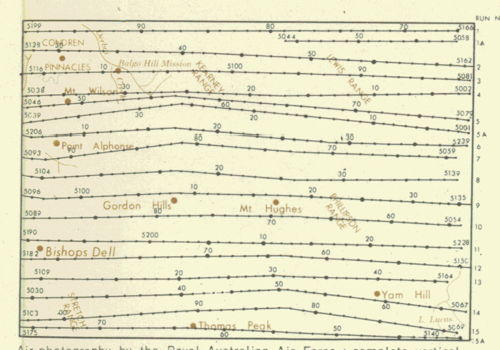


B Reconnaissance—regional traverses and air-photo interpretation

C Sketchy—air-photo interpretation

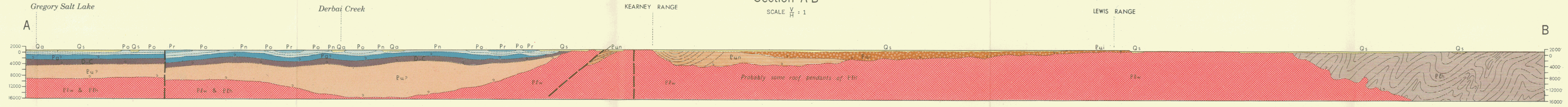
Geology by: J. N. Casey, A. T. Wells, B. H. Stinear, F. Reeves.
Compiled by: J. N. Casey, A. T. Wells. 1959
Drawn by Adastra Airways Pty. Ltd.

AIR-PHOTOGRAPH FLIGHT DIAGRAM



Air-photography by the Royal Australian Air Force; complete vertical coverage at 1 : 50000 scale; Mission Numbers 961, 965, 1013 - 1015 1056, July 1950

Section A-B



LUCAS

SHEET F 52-2

Printed by Mercury Press, Hobart

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or the Geological Survey of Western Australia, Perth, W.A.