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DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY

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THE QUATERNARY ERA

by

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QUATERNARY STUDIES SECTION

D.M. 789/67

14th January, 1969

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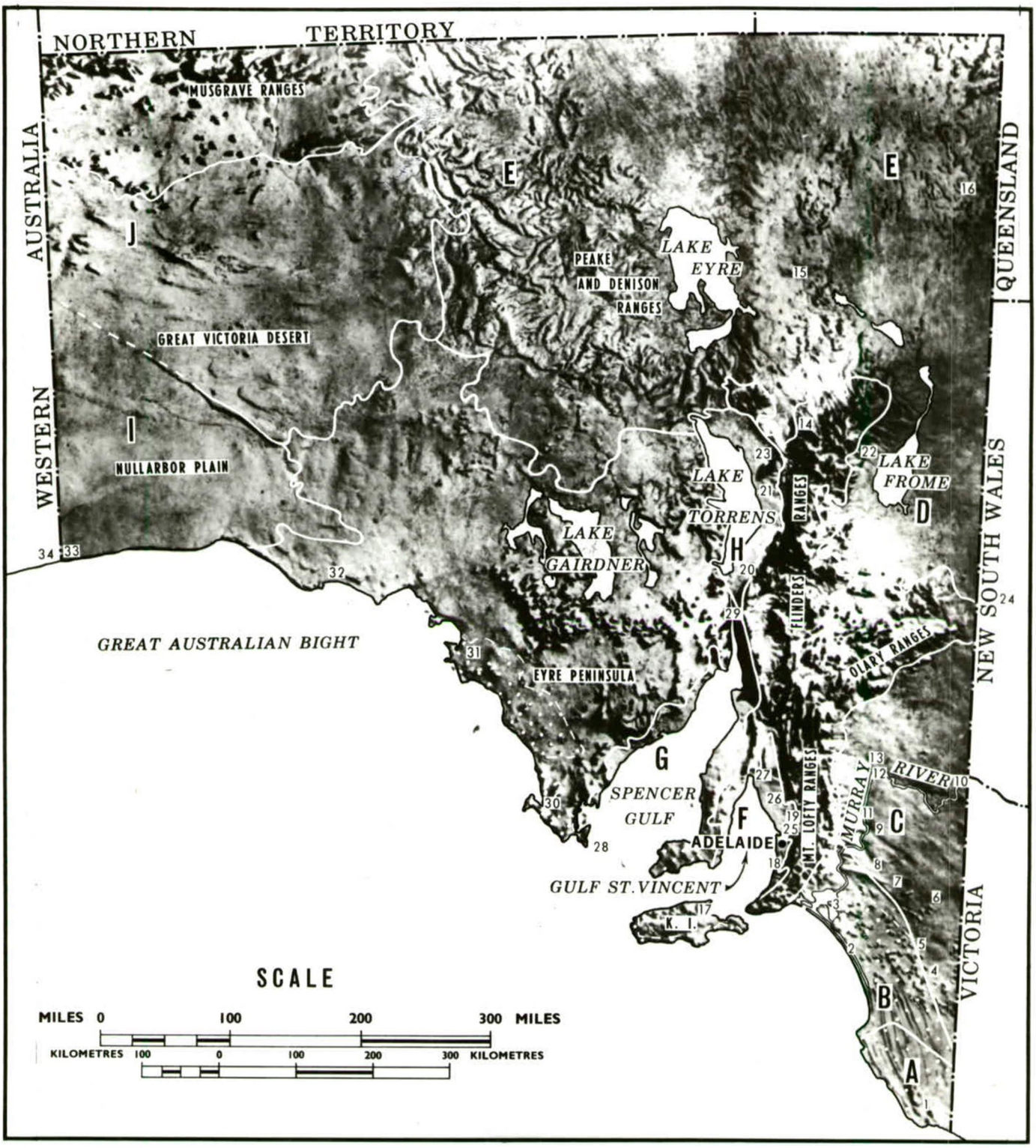

SOUTH AUSTRALIA SHOWING PRINCIPAL MORPHOLITHOLOGICAL SUDIVISIONS

WESTERN BASINS	WESTERN SHIELD	CENTRAL BASINS	HIGHLAND CHAIN	EASTERN BASINS
			MUSGRAVE RANGES	
J. OFFICER BASIN			PEAKE & DENISON RANGES	E. GREAT ARTESIAN BASIN
	LAKE GAIRDNER AREA	H. TORRENS BASIN	FLINDERS RANGES	D. FROME EMBAYMENT
		G. SPENCER BASIN	OLARY "RANGES"	
I. EUCLA BASIN	EYRE PENINSULA			C. MURRAY BASIN
		F. ST. VINCENTS BASIN	MT. LOFTY RANGES	
	AEOLIANITE DUNES	AEOLIANITE DUNES	K.I. KANGAROO ISLAND	B. PADTHAWAY RIDGE AEOLIANITE DUNES
				A. OTWAY BASIN

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THE QUATERNARY ERA

INTRODUCTION

The Quaternary Era includes the two periods known as the Pleistocene and the Recent (or Holocene). The Era, although relatively brief in the geological time sense in that it extends back for only about two million years, provides a vast amount of geological information. Whereas for earlier times, much of the record is destroyed by subsequent events, so much of the Quaternary record is preserved that selection of the most significant data for interpretive purposes is extremely difficult.

The Quaternary has seen the development of nearly all present day geomorphological features: mountain chains, drainage depressions and continental shapes. It has seen extensive glaciation: the growth and recession of polar and continental ice sheets, accompanied by related regressions and ingressions of the sea and exposure and inundation of the continental shelves. The Quaternary has also seen the advent of Man who by changing the superficial face of the land is acting as a geological agent of some significance.

Tectonics and Volcanicity

In South Australia, the tectonic movements which led to the break up of the Tertiary basins of sedimentation, commenced in the late Miocene and continued throughout the Pliocene into the Quaternary. These movements which are part of the Kosciuskan Orogeny are still continuing so that the physiographic features we now know as the Mt. Lofty and Flinders Ranges, the Lake Eyre and other inland depressions, and the many associated drainage systems, are all geologically young and are still being developed and modified.

The depression occupied by Gulf St. Vincent, Spencer Gulf and Lake Torrens reflects a compound system of downfaulted blocks (grabens)

bounded by uplifted areas in the adjoining ranges.

The rugged and often precipitous features of the Flinders Ranges are also evidence of continuing uplift and consequent youthful landforms. Convincing evidence for the recent upward movement of the basement can be seen in the Innamincka area where the rising basement has domed thick late Palaeozoic and Mesozoic sediments of the Great Artesian Basin with resultant radial drainage by ephemeral streams.

Yet another interesting feature of the Quaternary in South Australia is volcanic activity in the South East of the State and on Kangaroo Island. There appear to have been two separate phases: the older is represented by a series of vents extending from Mt. Graham southeasterly to The Bluff and including Mt. McIntyre. This group of vents has been affected by high sea levels of the Quaternary and obviously preceded the ingression of the sea, (Sprigg, R.C., 1952). The younger phase includes Mt. Gambier and Mt. Schank (see plate) features, which are unaffected by the high sea levels. Ash from Mt. Gambier has been dated at about 4,700 years B.P.* and 1,400 years B.P., suggesting two periods of activity both of which are within the time of occupation by aboriginal people.

Pleistocene Glaciation

The Quaternary glaciation which affected the highlands of eastern Australia and Tasmania has left no evidence that it extended into South Australia. However, the fluctuating sea level caused by the withdrawal of water into the ice caps and its periodic release has had a profound affect on climate, coastal configuration, and landscape development.

At times during the Pleistocene, shell debris resulting from wave action was blown inland to form the enormous fossil calcareous dunes (aeolianites) which are a feature of the coastline from Port McDonnell to the head of the Great Australian Bight. In the South East, stranded coastal dunes record a number of high sea levels. South of Kangaroo Island, the old course of the Murray River can be traced as a submarine feature incised into the

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Footnote: * Before Present (1950)

continental shelf during a relatively low stand of the Pleistocene Sea. This feature is now submerged up to 350 feet below present sea level. Field evidence also indicates that the sea in quite recent times has stood at 10 feet and possibly 25 feet above present level.

Both the older and younger volcanic phases are basaltic in type, but are principally ash eruptions. The basaltic lavas at Kingscote on Kangaroo Island ~~apparently~~ appear to belong to the older phase.

STRATIGRAPHY

It is an interesting and rewarding exercise to attempt to interpret Quaternary events and to place them in their correct time sequence. The stratigraphy of the Quaternary involves the study and interpretation of the layered materials including terrestrial sediments, - such as gravels, sands and clays - which are correlated on the basis of their physical continuity and on similarities in climatic and geomorphic environments. The materials in the waste mantle record changes in the kind and rate of weathering, in sedimentary processes, and in the formation of crusts and new derivative soils.

The stratigraphic units which are now mentioned are found across the southern portion of Australia. Some units link the record from the former ocean basins with the subsequent terrestrial deposits, and some soil units, including the surface chemical crusts known as calcretes, ferricretes and silcretes, provide an important means of stratigraphic correlation.

Quaternary stratigraphy of South Australia is most readily considered in five main provinces, viz. The Eastern Basins, the Highland Chain, the Central Basins, the Western Shield, and the Western Basins.

The Eastern Basins

Included in this province are the Murray and Otway Basins which are separated by the Padthaway Ridge, and the Great Artesian Basin to the north and east which is divided from the Murray Basin by the subdued easterly continuation of the mountain chain in the Olary area.

Tertiary sedimentation in the Murray Basin closed with deposition of the estuarine Norwest Bend Formation and its extensive fluvio-lacustrine equivalent the Parilla Sand. Silicification and ferruginisation marks the time break between Tertiary and Quaternary sedimentation. In the Chowilla area, a silicified quartz sand forms a cap on Parilla Sand. The ground surface at the time of silicification has been assigned to the Karoonda Surface (Firman, 1967). E.D. Gill (pers. comm.) has shown that the surface near Chowilla is a Pleistocene feature near the base of the Blanchetown Clay.

On the south side of the Murray Basin, on the Padthaway Ridge and in the Otway Basin, shallow marine fossiliferous sandy limestone and calcareous sand of the Coomandook Formation overlies Parilla Sand or older rocks and is in turn overlain by a wedge of aeolian Bridgewater Formation. Bridgewater Formation contains aeolian calcarenite and was originally defined in Victoria as "Calcareous dunes and dune limestones" (Boutakoff, 1963). In South Australia, the sequence has been subdivided into a lower and upper member separated by a calcreted zone known as the Ripon Calcrete. Lower member Bridgewater Formation crops out in many places as far south as Ashville and Keith, but in the lower south-east the few known occurrences of the lower member are scattered along the margin of the Padthaway Ridge.

Inland, in the Eastern Basins, thin fluvio-lacustrine sandy clay and limestone sequences are widespread. In most places in the Murray Basin these deposits overlie late Pliocene sediments. Near Lake Eyre, the clays rest upon ?Oligocene Etadunna Formation. Units in this stratigraphic position are the Blanchetown Clay and the Bungunnia Limestone in the Murray Basin, and the Avondale Clay, and other units variously described as freshwater limestones, gypsite sediments and gypseous lacustrine clays in the Great Artesian Basin. In some places, in the Frome Embayment for example, the thin sequences give way to graben deposits of gravels, sands and clays about 300 feet thick.

In some places on the southern coastal margin lower member Bridgewater Formation overlies the eroded top of the Pleistocene mottled clays. Inland, this erosion surface is overlain by dune sands and pebble conglomerates derived from Bungunnia Limestone and older rocks. The younger deposits and the stream patterns cut into the Pleistocene mottled clays and older deposits, have been preserved beneath a blanket of loess and associated calcrete. The oldest calcrete layer is the Ripon Calcrete, a thick and extensive

zone of cemented carbonate concretions, carbonate breccia and clastic material that was formed subaerially, largely by carbonate accumulation.

Upper member Bridgewater Formation forms a system of subparallel dunes overlying Ripon Calcrete on the coastal margin. Dune shapes are well preserved in this unit, as are root-like structures and randomly arranged reddened soil horizons, thin layers of loess and moderately hard calcrete. Freshwater limestone and Anadara-bearing shell beds in the southeast appear to have been laid down about this time.

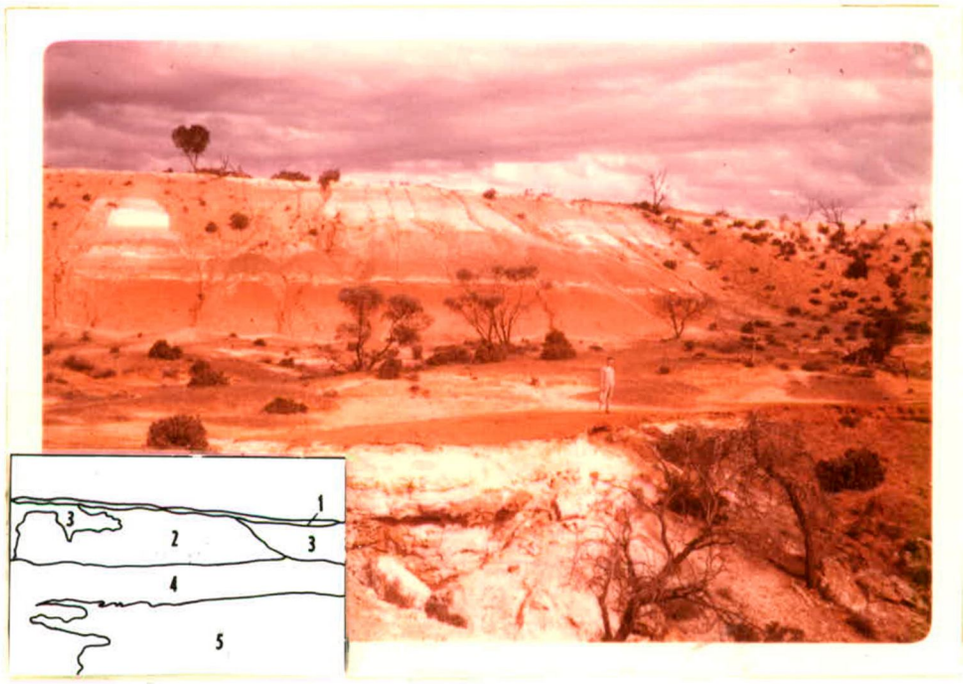
In the Murray Basin, younger calcrete layers coalesce with Ripon Calcrete to form a fossil soil layer between overlying aeolian sands and underlying deposits, including Pleistocene mottled clays. This soil unit, which is marked by younger moderately hard calcretes and which has Ripon Calcrete at the base in many places, is named the Bakara Soil.

Overlying the Bakara Soil in the Murray Basin are successive layers of aeolian sand which show, from oldest to youngest, progressive decalcification and lightening of colour due to removal of iron-oxide coatings from the grains.

The Woorinen Formation is the oldest widespread aeolian layer in the Murray Basin. It is a pale red-brown mixture of quartz sand and carbonate silt, and contains layers of soft platy or nodular calcium carbonate making a soil unit which is termed Loveday Soil. Subsequent dune formations are the red-brown Bunyip Sand, and yellow Molineaux Sand (both of which contain calcareous pipes), and pale grey recent surface sand.

In the coastal tract of the Otway Basin, estuarine clays and shell banks with a fauna found also in the Lipson Formation and the St. Kilda Formation of the Central Basins, are older than the Molineaux Sand. Younger coastal dunes, beach ridges and dunes in the lee of circular lagoons are probably equivalent in age to the Semaphore Sands of the Central Basins. Carbonate sediments forming in the Coorong Lagoon, peat in the coastal swamps, and the youngest of the three sets of mound springs in the Great Artesian Basin, are deposits associated with the modern landscape.

1. Murray Basin, near Renmark: (1) Nodular calcrete. (2) Massive sheet calcrete, (3) Bungunnia Limestone. (4) Carbonate silt, Photo by N. Duncan.



2. Murray Basin, River Murray Cliffs - left bank at Chowilla Damsite (1) Loveday Soil. (2) Blanchetown Clay. (3) Colluvium. (4) Karoonda Surface. (5) Parilla Sand. Photo M.N. Hiern.

The Highland Chain

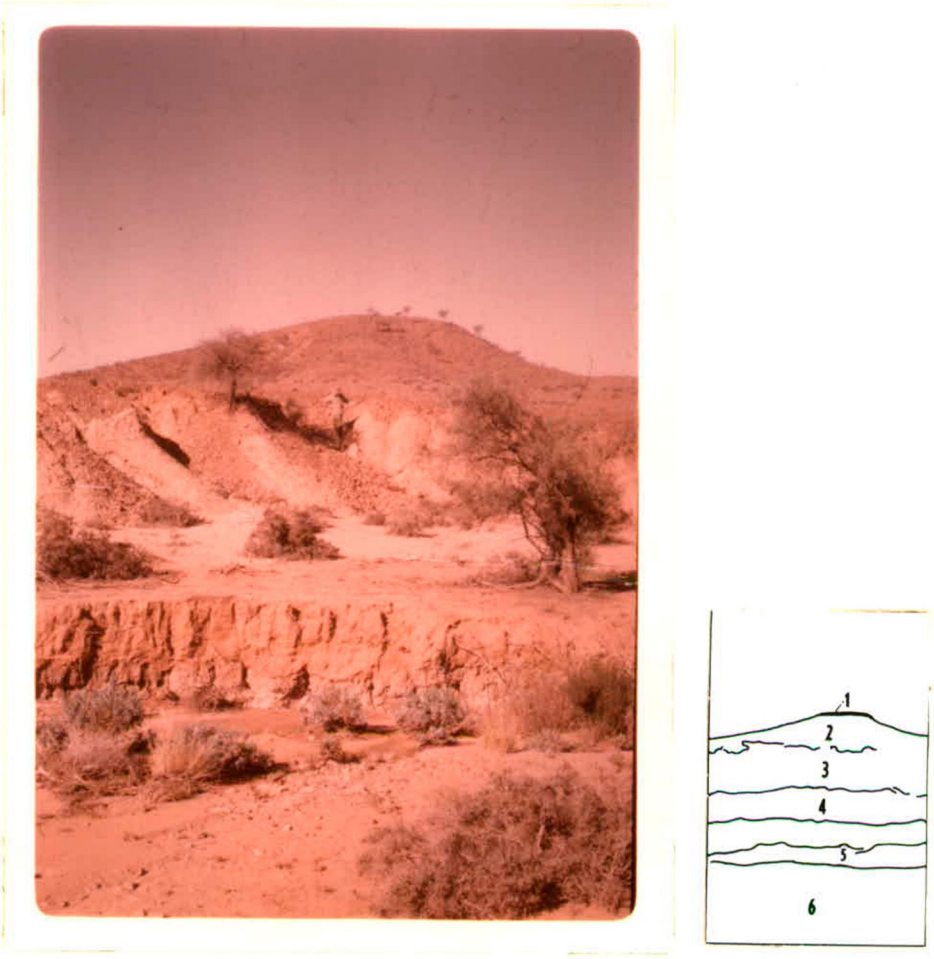
The ranges of the mountain chain rise little more than 1,500 feet above the plains, but the flat ground which borders them throws the steep slopes into sharp relief. The chain begins at Kangaroo Island in the south and extends through the Mt. Lofty Ranges to the Olary area near Broken Hill in the northeast, and through the Flinders Ranges, Peake and Denison Ranges to the Musgrave Ranges in the far northwest.

Tectonic and depositional events are recorded by erosional land forms in the ranges and by sedimentary deposits which are uplifted in the tract flanking the ranges or buried within the marginal basins.

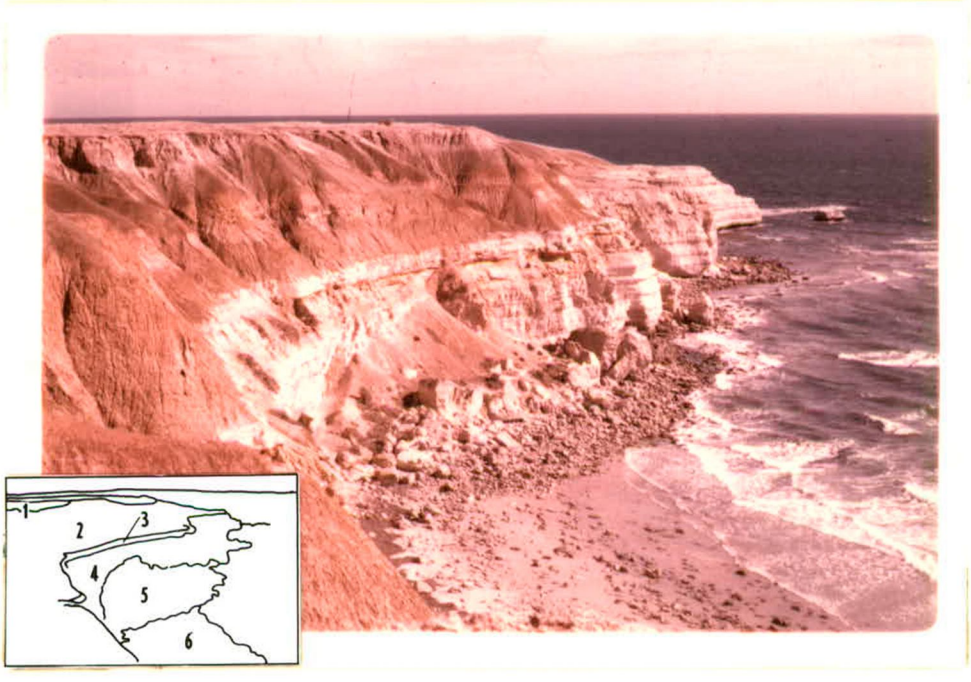
In the Mt. Lofty Ranges near Adelaide, the formation of the modern landscape began with the disruption of the mid-Tertiary land surface by block-faulting and tilting. Sediments of the Adelaide Plains and Myponga Basins, which in the Mid-Tertiary were contiguous, are now separated vertically by no less than 1,000 feet. Local changes in elevation ranging from a few feet to a maximum of about 400 feet can be demonstrated by tracing the lower Pliocene marine sediments across the Para Fault. The Keswick Clay, which is probably of middle Pleistocene age, is found at an elevation of about 150 feet above sea level near Adelaide on the Para Block, and about 600 feet above sea level south of the Eden Fault near O'Halloran Hill on the Eden Block.

In the Flinders Ranges an incipient peneplane which was transgressively covered by Mesozoic sediments has been raised and sculptured into young land forms. In a few places on the uplifted portion of the old surface, remnants of the Mesozoic sediments are preserved.

Extensive deposits of gravel are found in outwash fans flanking the Mt. Lofty-Olary and Flinders Ranges. The gravels are derived in part from silcreted deposits on the old Tertiary surface which, after Pleistocene uplift, were eroded, re-deposited and later calcreted. The oldest calcreted gravel is found in the Lyndhurst-Marree area, where it rests upon Avondale Clay and is probably the stratigraphic equivalent of the Ripon Calcrete. Younger calcreted gravels include the Telford Gravel, a unit which in the Beltana area overlies the Nilpena Limestone (probably the equivalent of the Bungunnia Limestone of the Murray Basin). The Telford Gravel was later sub-



3. Northern Flinders Ranges, Balcanoona area: (1) Lower member Telford Gravel. (2) Upper member Telford Gravel with Loveday Soil Carbonate. (3) Avondale Clay. (4) Alluvium over (5) Loveday Soil in Avondale Clay. (6) Alluvium of modern stream.



4. Mt. Lofty Ranges - Seaward margin of Clarendon Block near Blanche Point in the Willunga Basin area: (1) Calcrete over loess. (2) Ochre Cove Beds equivalent to Blanchetown Clay. (3) Hallett Cove Sandstone, upper bed of? Pleistocene limestone over a lower bed of Pliocene sand. (4) Blanche Point marls (5) Talus. (6), Modern beach.

jected to local erosion and re-deposition followed by development of the Loveday Soil. These gravels are better preserved and better developed on the flanks of the Northern Flinders Ranges than they are on the flanks of the Mt. Lofty-Olary Ranges to the south. The coarse grain size of the gravels formed during the Pleistocene indicates increased rates of erosion which can probably be linked with major withdrawals of the Pleistocene sea.

The Central Basins

These basins are developed parallel to the ancient crush zone. They follow a complex system of grabens which form the Great Australian Rift and lie immediately west of the tilted blocks or horsts of the Highland Chain. Similar grabens east of the chain are found in the Frome Basin and beneath the riverine plains in Victoria and New South Wales. Steeply dipping marginal faults separate the horsts and grabens. Development of the rift is recorded within the basins by thick sequences of clay, sand and gravel. Principal sedimentary basins within the rift are St. Vincent's Basin, Spencer Basin and Torrens Basin. The extent of the rift northwest of Lake Torrens is as yet unknown.

The St. Vincent Basin includes the extensive Adelaide Plains Basin, the Willunga Basin, Noarlunga Basin, Kingscote-Cygnet Basin, and shallow basins on the east coast of Yorke Peninsula.

The Pleistocene sequence begins with sands, limestones and clay with limestone lenses overlying late Pliocene Hallett Cove Sandstone, Dry Creek Sands or their equivalents.

The basal Pleistocene deposits are overlain by the Hindmarsh Clay, a sequence with sand and gravel lenses which are particularly abundant adjacent to the mountain slopes.

Along the southern coast within the basin, loess and Ripon Calcrete overlie lower member Bridgewater Formation or the Hindmarsh Clay.

On the upthrown side of marginal faults, Ripon Calcrete occurs as rubble or erosional remnants. On fault-line scarps it occurs as gravel in younger calcrete layers in Bakara Soil. Near Port Wakefield it occurs re-worked as beach gravel containing Anadara dated at more than 45,000 years B.P. On the downthrown side of marginal faults the Ripon Calcrete is preserved as

extensive sheets, in some places buried below 15 or 20 feet of younger deposits. Calcreted deposits post-dating Ripon Calcrete are stratigraphic equivalents of the yellow shelly sands and clays of Glanville Formation, which, in the Port Adelaide area, has a lime-cemented crust and contains Anadara dated at more than 45,000 years B.P. Pooraka Formation[1] is an important unit in St. Vincent Basin where it occurs as a sheet of clayey and silty fine sand with thin clay beds at the top. The formation is up to 20 feet thick and overlies the Hindmarsh Clay or Ripon Calcrete. Near the head of Gulf St. Vincent, Woorinen Formation occurs at the top of the unit. The Loveday Soil, with characteristic horizons of soil carbonate, has been developed in Woorinen Formation and at the top of Pooraka Formation and equivalent units elsewhere.

Overlying Pooraka Formation is the St. Kilda Formation which contains shallow marine, estuarine and beach ridge deposits. Shell from the top of this unit has been dated at about 1,100 years B.P. and shell from the base has been dated at about 4,000 years B.P. Overlying the St. Kilda Formation are the Fulham Sand and Semaphore Sand.

The Spencer Basin has a tectonic history during the Cainozoic which is similar to that of the St. Vincent Basin. Sedimentary sequences are similar, except that marine Tertiary rocks and aeolian Bridgewater Formation are restricted to the southern part of the basin. Glanville Formation is better developed and grades laterally into "lower member" Telford Gravel, and Pooraka Formation has a greater thickness, ranging up to 50 feet near Port Augusta. Woorinen Formation is well developed at the top of Yorke Peninsula. Soil stratigraphic units already described are present in the Spencer Basin. However, Loveday Soil contains abundant gypsum, a feature which probably reflects the climatic regime prevailing in this and other "inland" positions during formation of Loveday Soil.

In the Torrens Basin, Quaternary deposits include extensive dune fields of Fulham Sand, Woorinen Formation, sequences up to at least 50 feet thick of Pooraka Formation, and Avondale Clay (equivalent to Hindmarsh Clay)

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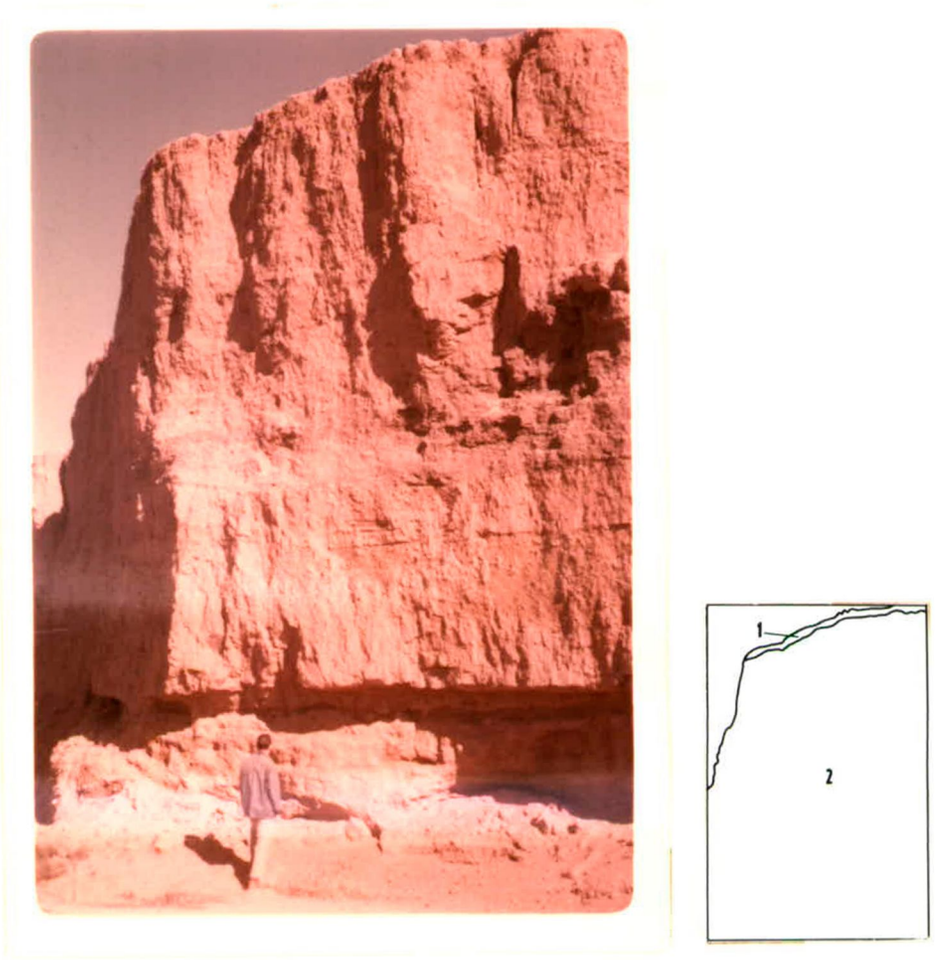
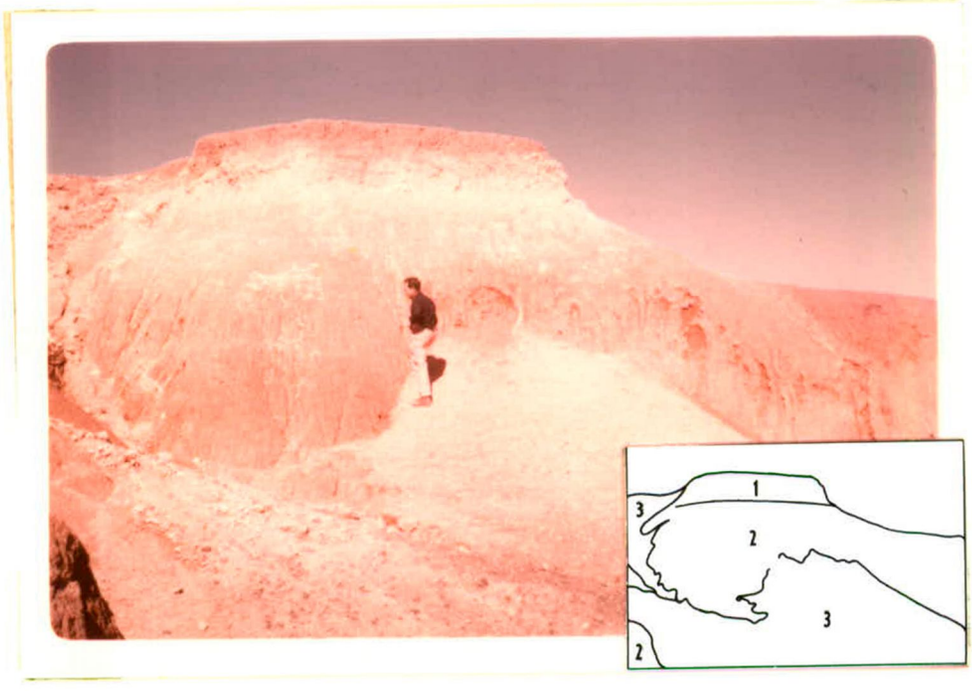
[1] Numerous bores put down in the St. Vincent's Basin have shown that sand forms a large part of this unit. The name has therefore been varied from Pooraka Clay to Pooraka Formation.



5. Flinders Ranges, Hookina Creek: (1) Loveday Soil. (2) Pooraka Formation.



6. St. Vincent Basin. Cliff section in the River Light at Red Banks east of Mallala. (1) Pooraka Formation; here a sandy slope deposit containing re-worked older calcrete and carbonate nodules of the Loveday Soil. (2) Hindmarsh Clay. (3) Talus over Hindmarsh Clay.

which is up to about 250 feet thick. Loveday Soil occurs everywhere throughout the landscape, except where it is veneered by Fulham Sand and thin younger deposits.

The Western Shield

This area includes the Eyre Peninsula and shallow lake depressions to the north near Lake Gairdner.

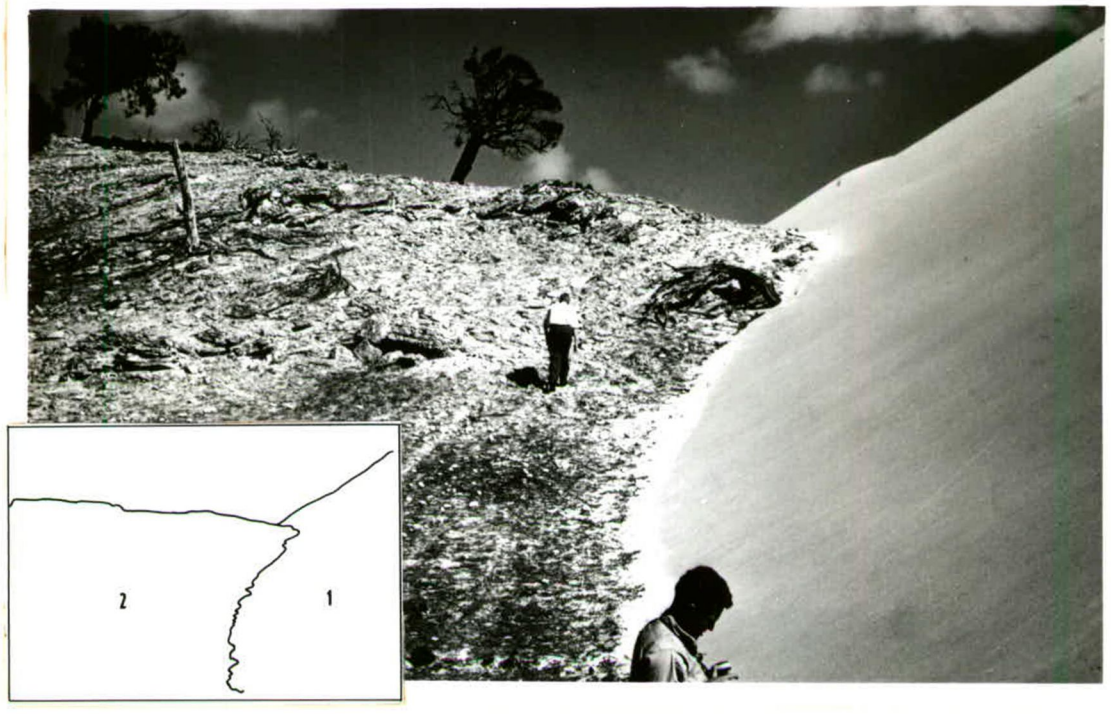
In the coastal zone, Pleistocene aeolian deposits of the Bridgewater Formation cover large areas. They rest upon silcreted slope deposits of possible Plio-Pleistocene age and upon a sequence of thin Tertiary and older sediments flanking numerous bed-rock highs. This pre-Pleistocene terrain is comparable with the Padthaway Ridge of the southern Murray Basin. The calcareous aeolianite, Bridgewater Formation, is reported to be up to 700 feet thick on Thistle Island near Port Lincoln. The relationships between lower member Bridgewater Formation, Ripon Calcrete, and upper member Bridgewater Formation are particularly well displayed in coastal cliffs in this area. Upper member Bridgewater Formation contains younger calcrete horizons of the Bakara Soil. An extensive sheet of shell sand, derived in part from Bridgewater Formation, veneers much of the coastal landscape. This is in the same stratigraphic position as Woorinen Formation and has Loveday Soil carbonate developed in it.

Inland, Pleistocene mottled clay or bedrock forms the base of the salt lakes, calcrete encrusts old bedrock surfaces, Loveday Soil occupies the plains or occurs in interdune areas between Fulham Sand in the salt lakes region, or Molineaux sand further south.

The Western Basins.

The Eucla Basin is a large, shallow basin which has a history generally similar to that of the Murray Basin until mid-Tertiary time. Since then it appears to have been an elevated non-depositional area in which the younger sediments characteristic of the Murray Basin are absent.

At the Head of the Bight, Bridgewater Formation aeolianite overlies Miocene Nullarbor Limestone. Inland, Ripon Calcrete appears on the surface of Nullarbor Limestone. Loveday Soil in aeolian sand sheets, and dune sand



7. Shield Area. Southern coastal margin near Coffin Bay: Fossil-fragment lime sands, the Coffin Bay facies of the Semaphore Sand (1), advancing over calcarenite (aeolianite) of the Bridgewater Formation (2). Photo R.K. Johns.

8. Shield Area. West Coast Basins on the southern margin: (1) Ripon calcrete. (2) Bridgewater Formation, lower member. (3) Reddened soil horizons. (4) Talus.

equivalent to the Fulham Sand forms a thin veneer infilling sink holes in many places.

Near the Western Australian border on the Roe Plain, Pleistocene sandy limestone rests directly on the Wilson Bluff Limestone. The fauna described in these deposits is similar to that of the St. Kilda Formation. Pleistocene calcareous sandstone with a similar fauna on the eastern fringe of the basin now occurs 120 feet above sea level (Ludbrook, 1958).

Calcareous sands equivalent to Semaphore Sand which are derived in part from the older aeolianite, form extensive dunes which extend westerly as far as the precipitous marine cliffs facing the Great Australian Bight. Near the Head of the Bight and at Eucla, towering coastal sand dunes rise steeply to bury the high cliffs.

The post-Tertiary formations of the Officer Basin are largely confined to the sand ridge area of the Great Victoria Desert.

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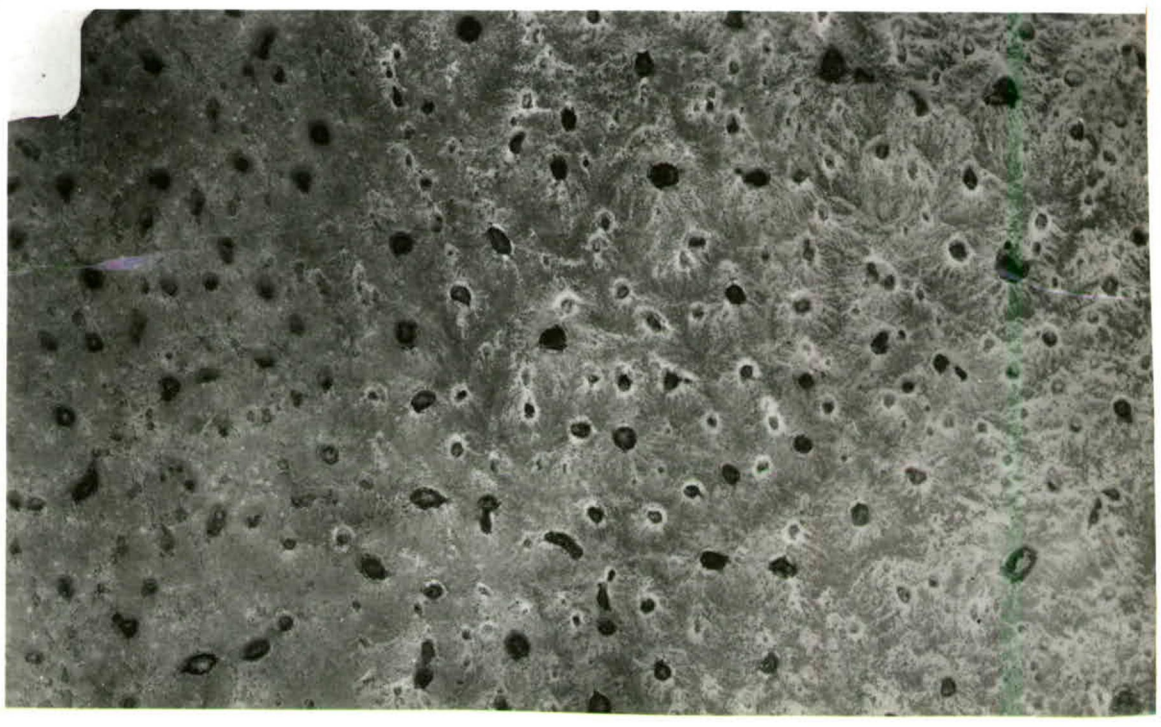

9. Western Basins: Claypans and vegetated depressions produced by in-filling of sink holes with Loveday Soil. S.A. Lands Dept. photo.

10. Eucla Basin: The entrance to Koonalda Cave, a prominent karst feature on the Nullarbor Plain. S.A. Mines Dept. photo.

REFERENCES

FIRMAN, J.B. 1967. Stratigraphy of Late Cainozoic Deposits in South Australia. Trans. Roy. Soc. S.A., Vol. 91 (1967) p. 170.

BOUTAKOFF, N. 1963. The Geology and Geomorphology of the Portland Area. Geol. Surv. Vict., Mem. 22 (1963) Table 1 and p. 43.

LUDBROOK, N.H. in GLAESSNER, M.F. and PARKIN, L.W. 1958. The Geology of South Australia. Jour. Geol. Soc. Aust. Vol. 5. Pt. 2 (1957). p. 134.

SPRIGG, R.C. (1952). The Geology of the South-East Province, South Australia, with special reference to Quaternary Coastline Migration and Modern Beach Developments, S.A. Dept. Min. Geol. Surv. Bull. 29 p. 57.