DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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PROPOSED ARTICLE IN TRANS. R. SOC. S. AUST.

FOSSILIFEROUS LOWER DEVONIAN BOULDERS IN CRETACEOUS SEDIMENTS OF THE GREAT AUSTRALIAN BASIN

GEOLOGICAL SURVEY

by

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SUMMARY

During 1977-78, 32 fossiliferous Lower Devonian quartzite boulders have been discovered within Mesozoic sediments along the southwestern margin of the Great Australian Basin. Previously only 2 such specimens had been discovered in South Australia though similar occurrences have been known in New South Wales since 1898. Fossil types not previously recorded in South Australia include the fish, Wuttagoonaspis, the brachiopods Howellella jaqueti and Sphaerirhynchia sp.; the bivalves Leptodesma inflatum, Sanguinolites sp. and Praectenodonta sp.; the gastropod Straparollus culleni; and abundant tentaculitids. Similar fossiliferous Devonian rocks are not known in situ in South Australia. The probable source area is the fossiliferous Amphitheatre and Mulga Downs Groups near Cobar in New South Wales. It is suggested that boulders were transported to South Australia during the Permian glaciation and then reworked into Cretaceous bouldery shales and sands. All but two of the boulders are found within conglomeratic sediments at the base of the Bulldog Shale. Theories on transport processes during the Cretaceous are discussed; it is concluded that comglomeratic sediments at the base of the Bulldog Shale are reworked debris-flow deposits.

INTRODUCTION

Fossiliferous Devonian quartzite boulders from Cretaceous sediments were first described from White Cliffs Opalfield in

New South Wales by Dun (1898). P.J. Russ+ collected the first South Australian fossiliferous boulder in 1966 from an opal shaft at the Andamooka Opalfield. It was thought at the time that an opal miner may have brought the boulder to South Australia from White Cliffs. However, after discovery of a second fossiliferous boulder near Dalhousie Springs by M.C. Benbow+, the geological implications were assessed by Campbell et al. (1977). They concluded that the fossiliferous boulders, like those at White Cliffs, were derived from the Devonian Amphitheatre Group near Cobar in New South Wales, and that they were transported to South Australia during the Permian glaciation, later to be reworked into Cretaceous strata.

During geological mapping of the BILLA KALINA 1:250 000 map sheet (R.B.F. & G.J.A.) and subsequent investigations elsewhere along the margin of the Great Australian Basin, a further 32 fossiliferous boulders were discovered, containing many species not previously recorded in South Australia. Their occurrence and distribution permit reassessment of their probable origin and modes of transport. The earlier concept of Campbell el al. (1977), based on only two fossiliferous boulders is substantiated.

GEOLOGICAL SETTING

Stratigraphic units in the southwestern Great Australian Basin include the Algebuckina Sandstone, Cadna-owie Formation and Mount Anna Sandstone Member, Bulldog Shale and overlying younger Mesozoic sediments (Fig. 1). The stratigraphic nomenclature adopted here is that of Wopfner et al. (1970) based on the Oodnadatta-William Creek area; for the Marree area see Forbes (1966).

The following geological summary is compiled from Wopfner & Heath (1963), Ludbrook, (1966), Wopfner et al. (1970),

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+Geological Survey of South Australia.

Morgan (1977), Carr et al. (1978), Pitt (1978), Vnuk (1978) and from observations during geological mapping of the BILLA KALINA 1:250 000 map sheet.

The Upper Jurassic Algebuckina Sandstone consists of fine to medium-grained sandstones and kaolinitic, conglomeratic sandstones. Clasts within the conglomeratic sandstones are chiefly rounded to well-rounded white quartz pebbles. However weathered acid porphyry and quartzite pebbles and cobbles are also common. The unit was deposited in a low gradient, fluviatile environment.

Transgression in the Neocomian led to the disconformably overlying Cadna-owie Formation, consisting of marginal marine very fine to medium-grained, micaceous and occasionally bouldery sandstones. Clasts within the bouldery sandstones are chiefly pebble, cobble and boulder-sized quartzites up to half a cubic metre. Later in the Neocomian, partial regression led to coarser sand deposition (Mount Anna Sandstone) which consists of medium to coarse-grained feldspathic and conglomeratic sandstones and micaceous sandstones. Clasts of porphyritic acid volcanics characterise the conglomeratic sandstones, though white quartz and quartzite clasts are also common. The clasts are sub-rounded to well-rounded and in the size range 0.02 to 0.2 m. Concave and festoon cross bedding are ubiquitous; foresets are up to 2 m in height and bedding within the foresets is graded.

The second Cretaceous marine transgression, in Aptian time, was of much greater extent and resulted in marine shale deposition (Bulldog Shale) over a large area of the Great Australian Basin. Basal lithologies of the Bulldog Shale range from bouldery to conglomeratic sands to grey shales, cone-in-cone limestones and sandy limestones. Fossil tree trunks are common. Clasts within the conglomeratic sediments are predominantly quartzites with minor acid porphyries and banded chalcedony and occur in either bioturbated grey shales or thin coarse-grained sand lenses (Fig. 2). The sand lenses vary from only a few centimetres thick to massive lenses up to a metre thick with boulders scattered in the sandy matrix (Fig. 3). These sediments interfinger with and are overlain by bioturbated dark grey shales and silts, and fossiliferous limestones.

A subsequent regression and a further two transgressive-regressive cycles occurred in the Albian to Turonian.

The fossiliferous Devonian quartzite boulder from the locality southeast of Oodnadatta is the only specimen weathered out from marginal marine sediments of the Cadna-owie Formation. All other fossiliferous boulders (including the original two specimens discovered at Dalhousie Springs and Andamooka, and previously thought to be derived from the Cadna-owie Formation) have weathered out from basal conglomeratic sediments of the Bulldog Shale.

DESCRIPTION OF THE BOULDERS

Basal conglomeratic sediments of the Bulldog Shale outcrop poorly and erosion has resulted in numerous clasts from the conglomerates, ranging in size from pebbles to boulders, forming a lag on the present day land surface (Figs. 4 & 5). Physically-resistant clast types dominate, mostly quartzites (feldspathic and/or lithic), with minor porphyritic acid volcanics and whitish-grey banded chalcedony. Granite, gneiss, quartz and shale clasts are rare, but may be locally more common near Proterozoic outcrops.

A high proportion of the quartzite boulders have abundant clay pellet impressions, a feature typical of the Upper

Proterozoic Arcoona Quartzite on the Stuart Shelf. The porphyritic acid volcanics are similar to the Middle Proterozoic Gawler Range Volcanics on the Gawler Craton (Wopfner et al. 1970), while banded chalcedony clasts are similar to cherts and siliceous concretions in the Cambrian Andamooka Limestone.

Less than 1% of all boulders contain Devonian fossils. Fossiliferous boulders are siliceous, feldspathic and lithic quartzites. They consist of quartz-rich, medium-grained sand (0.2 to 0.3 mm) and minor (< 10%) potash feldspar grains cemented by secondary quartz overgrowths. The lithic quartzites contain small fragments of sericitic schists and acid porphyries (Whitehead, 1978). It is not possible to distinguish unfossiliferous Devonian quartzites from other quartzite clasts.

No fossiliferous boulders have been observed in outcrop. They have been found only in the present day surface lag over eroded Mesozoic units (Figs 4 & 5).

FAUNAS OF THE BOULDERS

In the two fossiliferous Devonian boulders previously recorded in South Australia (Campbell et al. 1977), the specimen from Dalhousie Springs contained the brachiopod Howellella jaqueti (Dun) and bivalve Actinopteria sp: these were also present in the specimen collected from Andamooka. In the latter sample tentaculitids and brachiopod Isorthis sp were also present. Below is documented the fossil types discovered within the fossiliferous boulders during 1977-78*, and they include many species not recorded previously.

Billa Kalina locality 1 - 4 boulders

Fish plate:	Wuttagoonaspis sp. (see Fig. 6)	lat: 29°28'10"S
Brachiopods:	Howellella jaqueti (Dun) (see Fig. 7)	
	Brachiopoda indet.	long:136°08'00"E

*Specimens stored by Geological Survey of South Australia.

Bivalves: *Leptodesma inflatum* (Dun)

Bivalvia indet.

Tentaculitid: *Tentaculites* sp. (see Fig. 8)

Billa Kalina locality 2 - 2 boulders — lat: 29°28'00"S

Brachiopod: *Howellella jaqueti* (Dun) — long:136°06'50"E

Billa Kalina locality 3 - 2 boulders — lat: 29°58'20"S

Brachiopoda indet. — long:136°12'50"E

Bivalvia indet.

Fish plates & spines

Billa Kalina locality 4 - 3 boulders — lat: 29°57'30"S

Brachiopods: *Howellella jaqueti* (Dun) — long:136°18'35"E

Brachiopoda indet.

Bivalves: *Sanguinolites* sp.

Bivalvia indet.

Gastropods: *Straparollus culleni* (Dun) (see Fig. 9)

Holopea sp.

Murchisoniidae indet.

Echinodermata indet.

Fish Plates and spines

Billa Kalina locality 5 - 1 boulder

Tentaculitid: *Tentaculites* sp.

Crinoid ossicles — lat: 29°11'00"S

Bryozoa indet. — long:136°21'05"E

Billa Kalina locality 6 - 1 boulder — lat: 29°12'15"S

Bivalve: Bivalvia indet.

Crinoid ossicles — long:136°09'05"E

Billa Kalina locality 7 - 1 boulder — lat: 29°02'05"S

Brachiopod: Brachiopoda indet.

Crinoid ossicles — long:135°12'20"E

Billa Kalina locality 8 - 2 boulders

Brachiopods: Stropheodontid (probably (*Mesodouvillina* or *Mclearnites*) (see Fig. 10)

	Brachiopoda indet.		lat: 29°55'00"S
Tentaculitid:	<u>Tentaculites</u> sp.		
Crinoid fragments			long:135°49'30"E
Bryozoa indet.			
<u>Moolawatana</u> - 3 boulders			lat: 29°52'12"S
Brachiopods:	<u>Howellella jaqueti</u> (Dun)		long:139°38'00"E
	Brachiopoda indet.		
Bivalves:	<u>Leptodesma inflatum</u> (Dun)		
	Bivalvia indet.		
Tentaculitid:	<u>Tentaculites</u> sp.		
<u>Oodnadatta</u> - 1 boulder			lat: 27°55'30"S
Bivalve:	<u>Praectenodonta</u> sp.		long:135°46'40"E
Tentaculitid:	<u>Tentaculites</u> sp.		
<u>Stuarts Creek</u> - 7 boulders			lat: 30°05'45"S
Brachiopods:	<u>Sphaerirhynchia</u> sp.		
	<u>Howellella jaqueti</u> (Dun)		
Bivalves:	<u>Sanguinolites</u> sp.	(see Fig. 11)	long:137°11'30"E
Tentaculitid:	<u>Tentaculites</u> sp.		
Crinoid ossicles.			

DISCUSSION

<u>Faunas</u>

The faunas preserved in the boulders have not been recorded from Devonian sediments in South Australia. Fish scales in a mudstone were discovered between 817 & 823 m in Munyarai No. 1 within the Officer Basin, but were not positively identifiable (Gilbert-Tomlinson 1969). No bivalves or brachiopods are known in the state, nor are the faunas of the boulders known from sediments in the Amadeus and Georgina Basins. However both the lithologies and faunas are very similar to those of the Amphitheatre and Mulga Downs Groups near Cobar in New South Wales. Marine Lower Devonian sandstones with comparable invertebrate faunas to those at Cobar are known from the Mt Ida Formation of central Victoria and the Eldon Group of western Tasmania. These have been considered as alternative source areas but the absence of Notoconchidium from the boulders in South Australia is taken as evidence against a Victorian or Tasmanian source because this genus is relatively common in a durable quartzite in both these areas. Also Notoconchidium is among the more common fossils in the fossiliferous Lower Devonian boulders from Permian diamictites in Victoria.

A second feature for comparison with Victoria is the abundance in South Australian boulders of Howellella jaqueti. Although Howellella occurs in a variety of forms at Heathcote, Talent (1965, p. 37) records that they are poorly preserved. The genus is also poorly represented in the Eldon Group. In the South Australian boulders it is one of the most common forms, as it also is at several horizons in the Amphitheatre Group.

Although we now have many more specimens with a wider range of species than we knew previously, we can still match the entire invertebrate fauna with that from the Amphitheatre Group. This is not a conclusive argument because the fauna from the Eldon Group has not been completely described, so that a future comparison might be made.

Most importantly, fossil fish fragments have now been found in two boulders. So far as we are aware, no Devonian fish beds are known from Tasmania, though they are well exposed in central and eastern Victoria and over much of central New South Wales. The most important discovery is the fragment referred to as Wuttagoonaspis, a genus described by Ritchie (1973) from the Mulga Downs Formation in the Mt Grenfell area west of Cobar, and Mt Jack north of Wilcannia. As yet not known elsewhere, this specimen is only a fragment of an undetermined bone, but its ornamentation is distinctive, and its identification has been confirmed by Dr. Ritchie (Australian Museum, Sydney).

We therefore conclude from the available evidence that the source for the fossiliferous boulders is in the Cobar region, the boulders having been transported at least 1,000 km in a westerly to northwesterly direction.

<u>Primary transport processes</u>

A palaeoenvironmental interpretation of Jurassic-Cretaceous sediments in the southwestern Great Australian Basin by Wopfner et al. (1970) indicates that transport of boulders this direction and distance during the Mesozoic was improbable. However Permian ice may have transported the fossiliferous boulders from the Cobar area to northern South Australia, and the unconsolidated Permian diamictites could then have been reworked into Mesozoic sediments (Campbell et al. 1977).

In northern South Australia, Permian sediments are preserved in Palaeozoic basins under the Great Australian Basin (e.g. Arckaringa, Cooper and Pedirka Basins) and in small grabens within the Gawler Block, but they have been largely removed from uplifted areas. One facetted boulder was observed in Cretaceous sediments 75 km south of Oodnadatta (Jack, 1915) and a striated boulder was observed near Dalhousie Springs (Woolnough & David, 1926), and these boulders may represent clasts reworked from Permian diamictites (Parkin, 1956). However, most of the boulders are well-rounded and any glacial features have been removed.

Crowell & Frakes (1975) on the basis of distribution of glacial till and fluvial sediments and from palaeocurrent analysis, postulated a large Permian continental ice cap over northwestern New South Wales, with glacial debris being shed eastwards and possibly westwards into the basins of northeastern South Australia. This interpretation differs from that of Wopfner (1970) who concluded that the composition of erratics in Permian diamictites of the Arckaringa Basin indicated local glaciation rather than a continental ice sheet. He suggested that Permian glaciers originated on upfaulted highland areas; glacial debris was dumped along basin margins and then transported by mudflows and turbidity currents into distal parts of the basins.

There is no independent evidence supporting the theory of transport of material from the Cobar area to northern South Australia during the Permian. No fossiliferous boulders have been discovered in any Permian diamictites, ice-movement directions during the Permian are not known for northern South Australia and there are conflicting views on the Permian palaeoenvironment and likelihood of long-distance transport. However, Permian ice rafting is at present the only feasible model for transporting boulders from the Cobar area to northern South Australia.

Secondary transport processes

The processes by which large boulders, including the fossiliferous Devonian quartzites, have been deposited in a dominantly shaley Cretaceous sequence have invoked considerable discussion for nearly 100 years. Brown (1902), Jack (1915) Woolnough & David (1926) and Vnuk (1978) considered ice rafting was responsible for the transport of boulders weighing up to 2 tonnes over distances ranging up to 150 km. This theory was rejected by Parkin (1956) because of the lack of glacial features and probable warm tropical predicted for the Cretaceous. Warm climatic conditions during the Cretaceous were also inferred by Dorman & Gill (1959) from oxygen isotope palaeotemperature determinations on three Aptian belemnites which yielded a mean temperature of 15.4°C.

Woolnough & David (1926) also considered, but rejected, tree rafting as a possible transport mechanism for the boulders. Much later Wopfner et al. (1970) reinstated the proposal because of the abundance of fossil wood in Early Cretaceous sediments. However because of the abundance and concentration of boulders within particular horizons, tree rafting was not accepted as the sole transport mechanism. Since they considered the boulder beds to be restricted to margins of basement highs, they also proposed that the boulders originated on shorelines and migrated downslope by slow sediment creep.

Large boulders in a dominantly bioturbated shaley sequence at the base of the Bulldog Shale may indicate reworked debris-flow deposits. Bouldery debris-flow deposits typically consist of a massive fine-grained matrix with randomly dispersed boulders (Fisher 1971; Middleton & Hampton 1973; Carter 1975; Hampton 1975). The dominance of physically high-resistant, well-rounded cobbles and boulders in the Cretaceous sediments indicates the debris flows originated from a high energy shoreline environment. Boulders, cobbles and sand were transported in a clay-rich, watery matrix basinwards over low angle slopes. The debris flows were episodic events, permitting time for reworking of the debris-flow sediments, shale sedimentation and bioturbation. Winnowing of muds and fine sands from the debris-flow sediments by currents and possibly by waves has resulted in boulders and cobbles concentrated in thin, coarse-grained sand lenses. Complete winnowing of the fines and further shale deposition has resulted in some boulders being located within bioturbated shales.

Clast populations

Within the basal conglomeratic sediments of the Bulldog Shale, clasts are mainly rounded to well-rounded quartzites and minor acid porphyries and chalcedony. The bulk of the quartzitic boulders are though to be Upper Proterozoic quartzites that may have been derived directly from outcrops during the Mesozoic. Similarly the chalcedony clasts may be derived from the Cambrian Andamooka Limestone and some of the acid porphyry clasts from the Middle Proterozoic Gawler Range Volcanics on the Gawler Craton. The fossiliferous quartzite boulders (and possibly some of the acid porphyries) are thought to be reworked from Permian diamictites. However, the populations and lithologies of clasts within the Permian and Mesozoic sediments are very different. On the other hand, in the Permian diamictites, the clasts range in size up to 3 m and include limestone, schist, gneiss, granitic rocks, acid porphyry, quartzite, quartz, banded iron formation, chert and shale.

One explanation for this difference in clast lithologies and populations is suggested from the tumbling mill experiments of Abbott & Peterson (1978). Chert, quartzite and rhyolite were found to be the most durable rock types, followed by metabreccia odsidian, metasandstone, gneiss, granitic rocks, metabasalt, marble and schist. These results confirm that only highly resistant clasts dominate in the basal conglomeratic sediments of the Bulldog Shale. Hence it must be concluded that the fossiliferous Devonian quartzite and acid porphyry boulders, though forming only a small proportion of clasts in the Permian diamictites, have been concentrated in the Mesozoic sediments by reworking in a shoreline environment with the consequent elimination of the less durable types.

ACKNOWLEDGEMENTS

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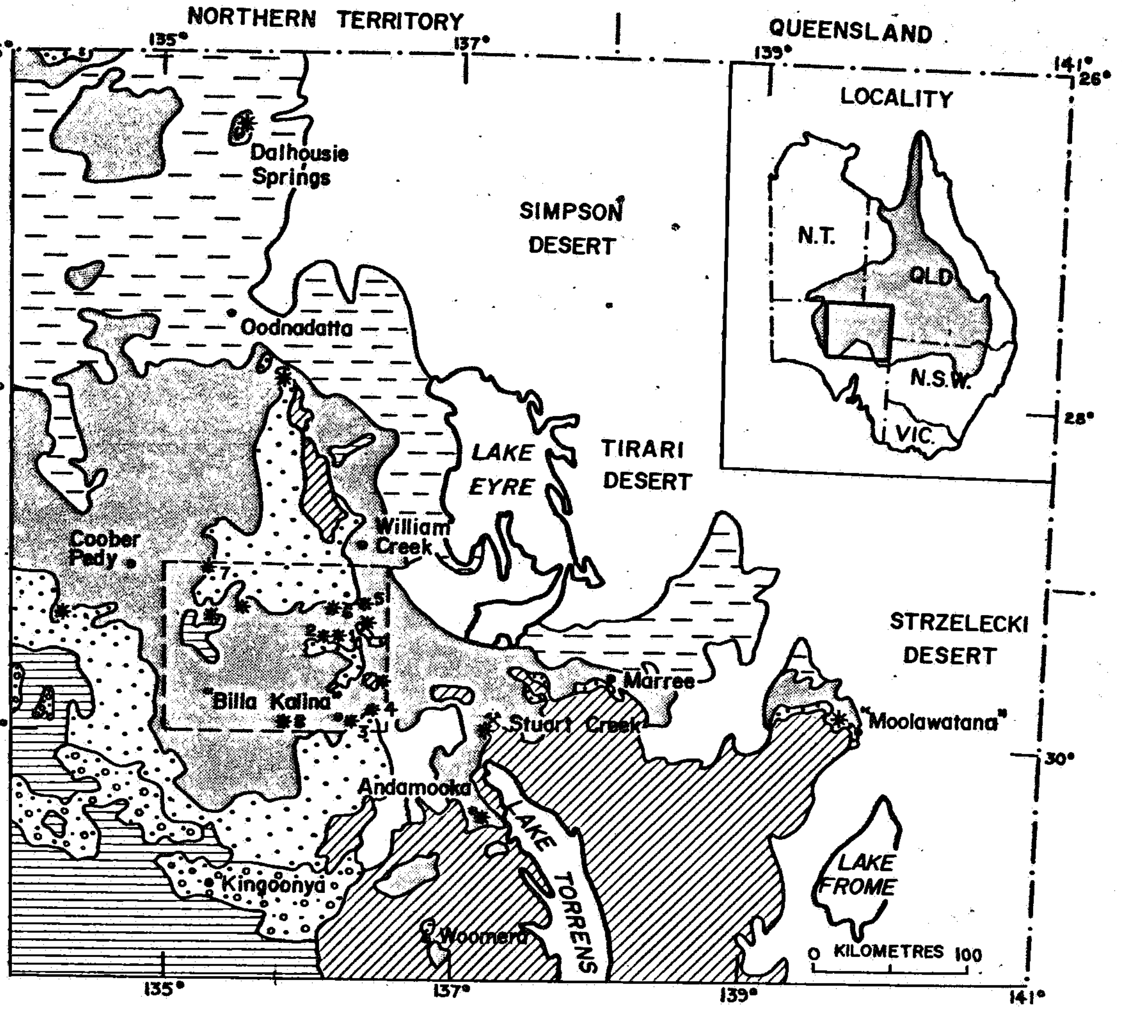

CAINOZOIC — Tertiary and Quaternary sediments.

MESOZOIC — CRETACEOUS (NEOCOMIAN, APTIAN, ALBIAN, TURONIAN); UPPER JURASSIC

Overlying Cretaceous marine sediments.

BULLDOG SHALE:
Marine shales and limestones.
Basal unit of bouldery and conglomeratic sands, shales, cone in cone and sandy limestones.

CADNA-OWIE FORMATION:
Fluviatile and marginal marine conglomerates and sandstones.

ALGEBUCKINA SANDSTONE:
Fluviatile conglomerates and sandstones.

PROTEROZOIC — CAMBRIAN; UPPER; LOWER-MIDDLE

Rock units of the Adelaide Geosyncline and Stuart Shelf.

Older basement rocks of the Gawler Craton.

✱ Fossiliferous Devonian quartzite boulders.

Billakalina 1:250 000 map sheet.

FIG. I

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: 1:5 000 000
COMPILED: R.B. Flint	FOSSILIFEROUS DEVONIAN BOULDERS IN CRETACEOUS SEDIMENTS – GREAT AUSTRALIAN BASIN	DATE: 26-6-79
DRN: K.W. / CKD:	LOCATIONS AND REGIONAL GEOLOGY SOUTH AUSTRALIA	PLAN NUMBER S 14116

1434

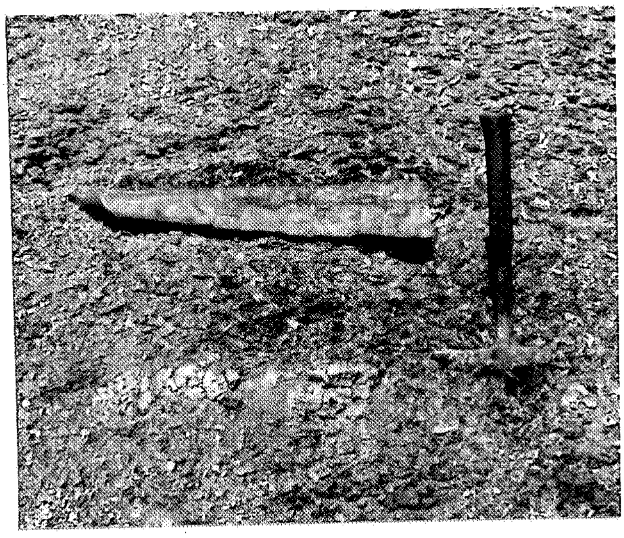

FIGURE 2

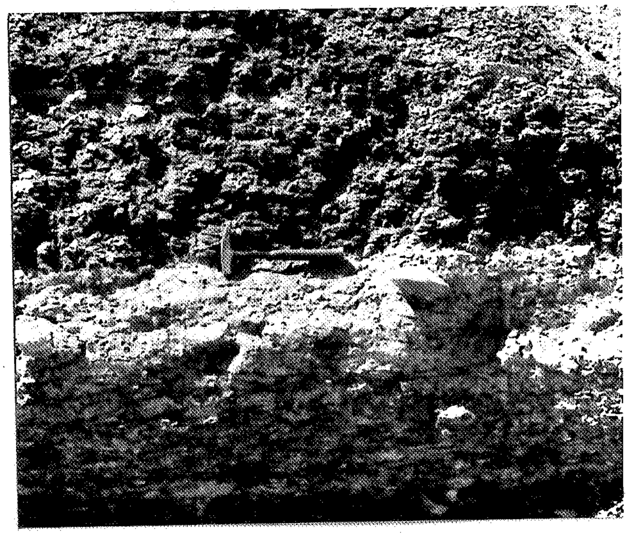

FIGURE 3

FIGURE 4

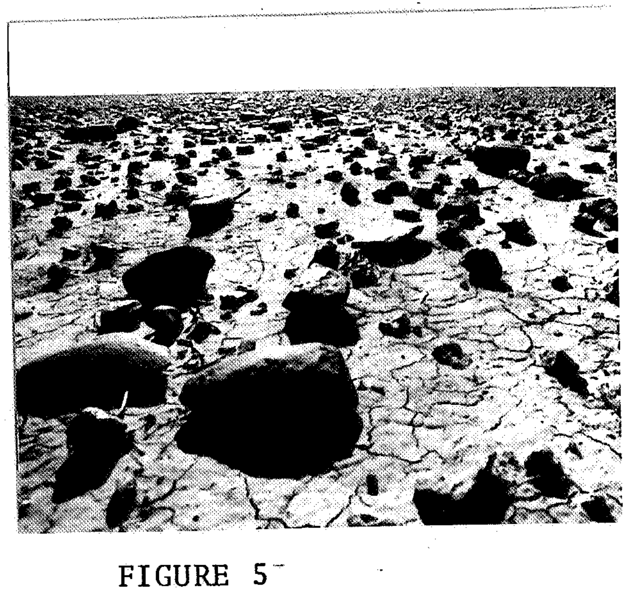

FIGURE 5

FIGURE 6

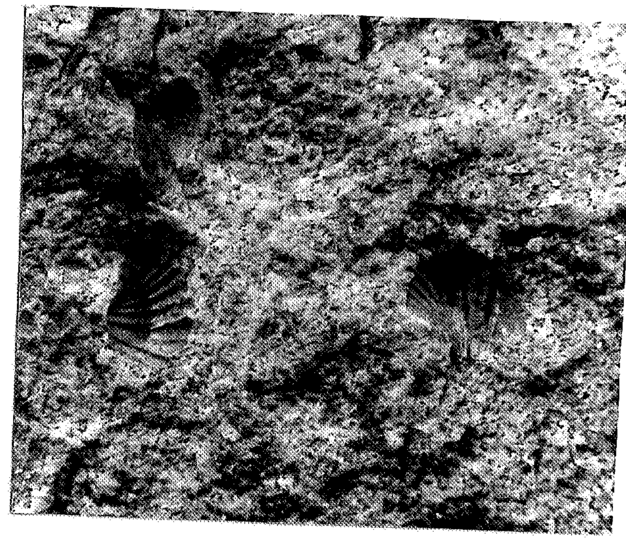

FIGURE 7

FIGURE 8

FIGURE 9

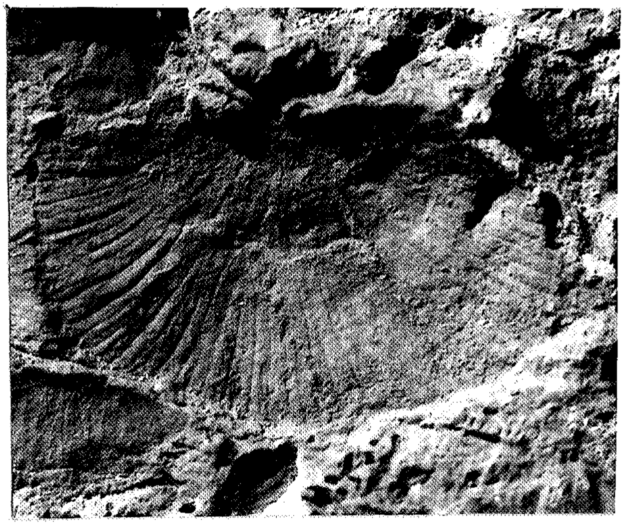

FIGURE 10

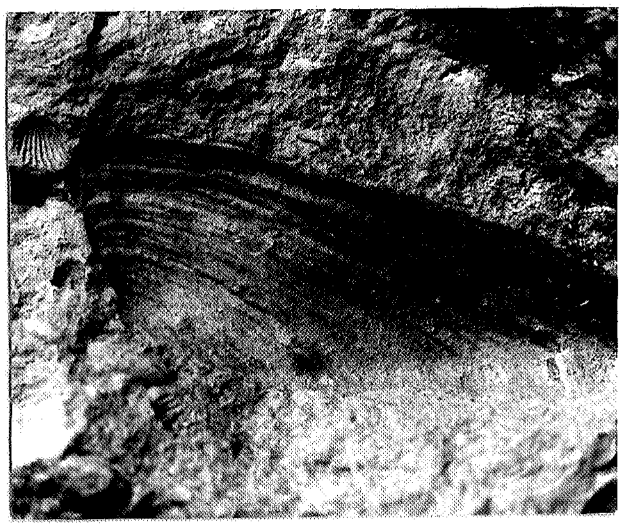

FIGURE 11

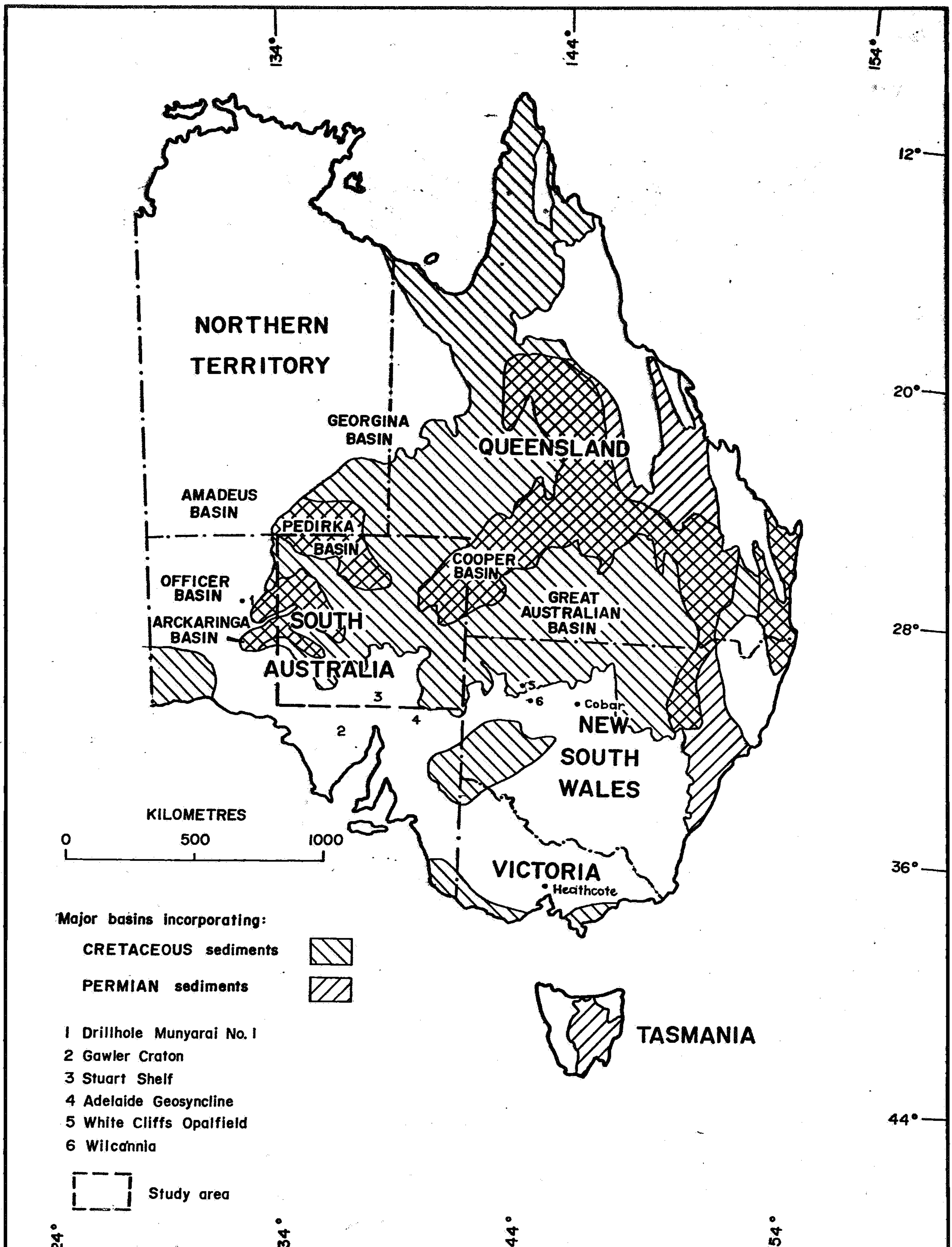

FIG. 12

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: 1:20000000
COMPILED: R.B. Flint	FOSSILIFEROUS DEVONIAN BOULDERS IN CRETACEOUS SEDIMENTS – GREAT AUSTRALIAN BASIN	DATE: 26-6-79
DRN: K.W. CKD:	**LOCALITY MAP**	PLAN NUMBER **S14117**

1434