10.—Vertebrate Localities in the Triassic Blina Shale of the Canning Basin, Western Australia

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The Blina Shale is recorded from the Fitzroy Trough which occupies the northern sector of the Canning Basin.

The author, as a member of a joint expedition to the Fitzroy Trough from the Western Australian Museum and the Museum of Palaeontology, Berkeley, California, stratigraphically mapped the Blina Shale at Erskine Range. An important fossil vertebrate collection was made here.

Other localities mapped as Blina Shale were prospected and two new localities were discovered. At one of these (1½ miles ENE. of Bore 20, Noonkanbah Station) a certain amount of useful vertebrate material was found.

Detailed descriptions of the 104′ of Blina Shale and 58½′ of Erskine Sandstone exposed at Erskine Range are given below.

The sedimentary characters and the palaeo-ecological implications of the fauna and flora indicate that deposition took place on the sub-aqueous topset plain of a marine delta.

Introduction and Previous Work

The Blina Shale is recorded from the central portion of the Fitzroy Trough which occupies the northern sector of the vast Canning Basin in the north west of Western Australia. The formation, however, is poorly exposed in the Trough and no type section has been described.

Geologists of the Bureau of Mineral Resources spent several field seasons in the Fitzroy Trough from 1948 through to 1952 (Guppy, Lindner, Rattigan and Casey 1958). They mapped the Blina Shale at Erskine Range and also identified several outliers of this formation in marginal synclines. Brunnschweiler spent some time in the field with the Bureau parties, and later, working with Bureau collections, recognised Triassic affinities in the fauna of the Blina Shale. He described a vertebrate and invertebrate fauna from the formation, noting the presence of a basal "bone bed" (in the Dry Corner area, approx. 124° 07′ E., 18° 21′ S.) and ascribed the Blina Shale and the overlying Erskine Sandstone to the Upper Triassic, suggesting that the two units be included in the Derby Group (Brunnschweiler 1954). This was the first record of marine Triassic in the Fitzroy Trough. Brunnschweiler argued that a slight angular unconformity separated the Blina Shale and the underlying Permian Liveringa Formation but more recent work indicates that these formations are disconformable. The microplankton suite of the Derby Town Bore (McWhae, Playford, Lindner, Glenister, and Balme 1958 p. 83) shows no considerable break between the Blina Shale and the Liveringa Formation, and Balme has suggested a Lower Triassic age for the Blina Shale, with affinities to the Kockatea Shale in the Perth Basin.

The Kockatea Shale is Lower Triassic in age (Dickins, McTavish, and Balme 1961).

Hitherto there has been no record of fossil vertebrates from the upper part of the Blina Shale.

Method

General

On the initiative of Professor R. A. Stirton, Director, Museum of Palaeontology, Berkeley, California, it was decided to equip a joint expedition to the Fitzroy Trough from the Museum of Palaeontology, Berkeley, California, and the Western Australian Museum.

The expedition consisted of Professor C. L. Camp, party leader, and Mr. J. Cosgriff, both of the Museum of Palaeontology, and Mr. D. Merrilees and the author, both from the Western Australian Museum and the University of Western Australia. Dr. W. D. L. Ride, Director, Western Australian Museum, was with the party in the initial stages until the arrival of Merrilees.

In the field the plan was to visit and prospect every outcrop of the Blina Shale for fossil vertebrates. The best areas would then be selected for further detailed work, with the Americans specialising in the palaeontology and the Australians doing the mapping. The success of the mapping project owes much to the ready assistance of Merrilees.

Consequently, when it was decided to concentrate on the Erskine Range locality, Camp and Cosgriff prospected and quarried proven beds in the area while McKenzie and Merrilees mapped the thickest exposed section.

Lithological samples are deposited in the collection of the Western Australian Museum, and the vertebrate collections have been divided by agreement between the Museum of Palaeontology, Berkeley, California, and the Western Australian Museum.

Mapping

A West Australian Petroleum Pty. Ltd. gravity station GM 75 11277 in the Erskine Range was used as a height datum and closed traverses were run to all quarry localities in the Range. This part of the mapping was carried out at a scale of 1″ = 200′. The detailed mapping of the section at Locality 4 was carried out at 1″ = 100′ (see Fig. 1).

Plane table and telescopic alidade were used to map the exposures. Where exposures were

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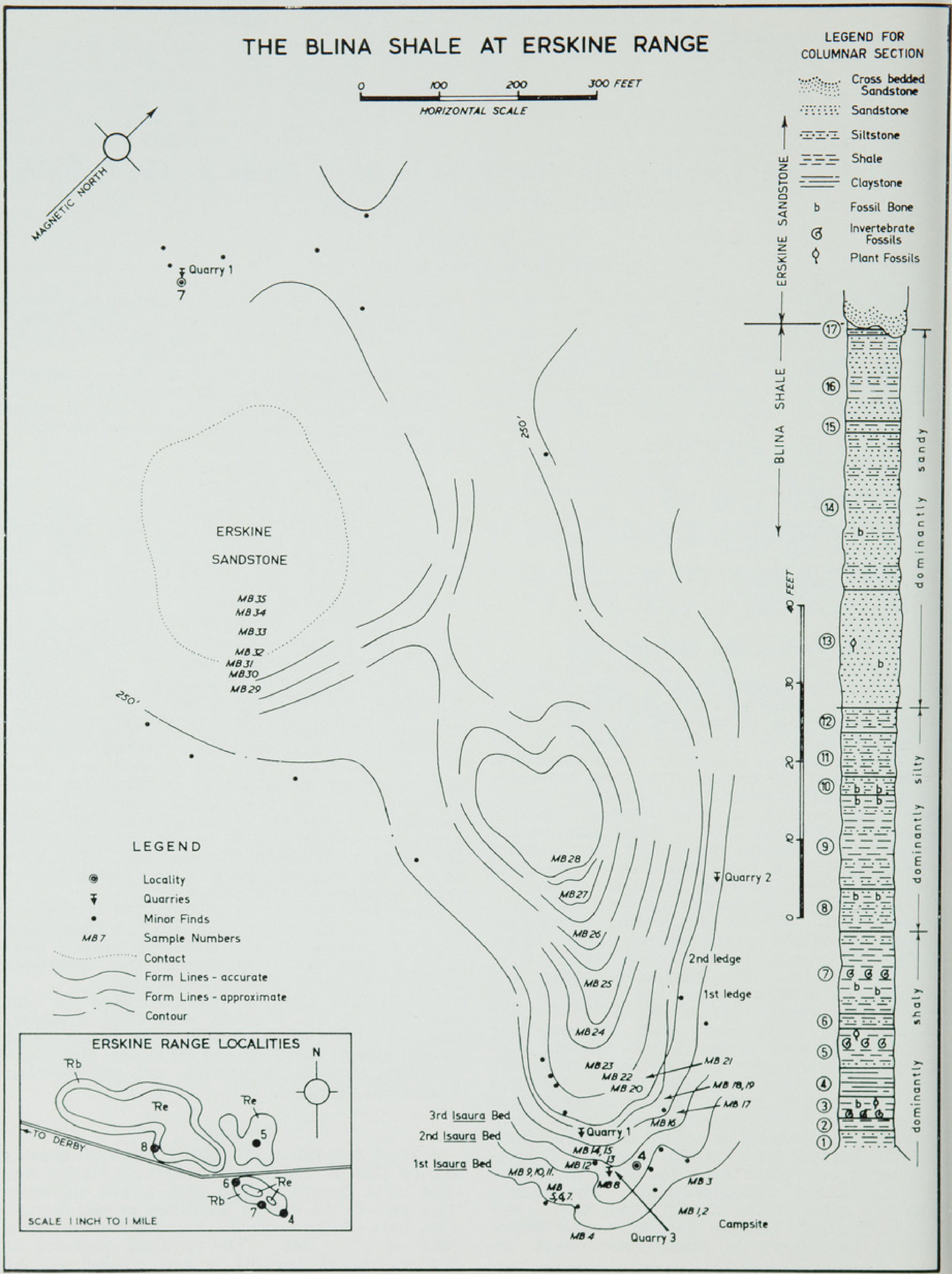
THE BLINA SHALE AT ERSKINE RANGE
0 100 200 300 FEET
HORIZONTAL SCALE
MAGNETIC NORTH
LEGEND FOR COLUMNAR SECTION
Cross bedded Sandstone
Sandstone
Siltstone
Shale
Claystone
b Fossil Bone
Invertebrate Fossils
Plant Fossils
ERSKINE SANDSTONE
BLINA SHALE
FEET
dominantly sandy
dominantly silty
dominantly shaly
Quarry 1
ERSKINE
SANDSTONE
MB 35
MB 34
MB 33
MB 32
MB 31
MB 30
MB 29
250'
LEGEND
Locality
Quarries
Minor Finds
MB 7 Sample Numbers
Contact
Form Lines - accurate
Form Lines - approximate
Contour
ERSKINE RANGE LOCALITIES
N
TO DERBY
SCALE 1 INCH TO 1 MILE
MB 28
MB 27
MB 26
MB 25
MB 24
MB 23
MB 22
MB 20
MB 21
MB 18, 19
MB 17
MB 16
Quarry 2
2nd ledge
1st ledge
3rd Isaura Bed
2nd Isaura Bed
1st Isaura Bed
MB 14, 15
MB 12
MB 9, 10, 11.
MB 5, 6, 7.
MB 8
MB 3
MB 1, 2
MB 4
Quarry 3
Campsite

Fig. 1

covered by scree, as commonly happened, the hillside was dug into until fresh rock was exposed. Where exposures were poor in the vertical plane, but better to left or right, beds were traced to these better exposures and the sectioning continued. In this way the whole Blina Shale section exposed at Locality 4 was mapped with only one break. This break occurred at the top of the most southerly hill in the Range (Locality 4). From this point the mapping was transferred to the next hill to the north. As the Blina Shale dips uniformly, it was possible to compute the stratigraphic position of the break so that the section could be compiled without loss or overlap.

The lithology was recorded in detail throughout the section and samples were taken at frequent intervals.

Following completion of this part of the programme, the Blina Shale/Erskine Sandstone contact was mapped at Localities 4, 6, 7 and 8 to test whether it was a disconformity (see Fig. 1).

Mapping at Erskine Range was completed in eleven days. No mapping was done elsewhere.

Stratigraphy of the Blina Shale

The outcrop at Erskine Range is the major exposure of Blina Shale in the Fitzroy Trough. Only one other outcrop can be located stratigraphically with any precision; at Dry Corner the basal beds are exposed but the contact with the nearby underlying Liveringa Formation is not.

The only area visited which afforded any scope for further palaeontological work or for stratigraphic correlation, was Erskine Range where the Erskine Sandstone/Blina Shale contact is more or less well exposed throughout the whole range. Detailed stratigraphic mapping, therefore, was commenced at Locality 4 (124° 21′ 40″ E., 17° 51′ 25″ S.), Erskine Range, in conjunction with a more intensive search for vertebrate material. Since the top of the sequence is missing at Locality 4, the upper 11½′ of section was mapped in the next hill to the north.

In this area the Blina Shale strikes N70 W and dips uniformly 01° NE.

The section measured is shown below:

Erskine Sandstone overlying:

		Thickness Feet
(Contact zone)	*sandy siltstone*, quartzose, slightly micaceous, ferruginised, purplish, hard, thickness varying up to 1 in., in places includes horizons containing light coloured, flat silt pellets.	
(17)	*sandy siltstone*, quartzose, micaceous, light coloured to purplish to yellow-brown, thin-bedded, laminated with colour-variegation between laminae	0-½
(16)	*sandy siltstone to sandstone*, quartzose, micaceous, light brown to whitish, some iron-staining, weathers friable, thin-bedded, in part laminated with slight colour-variegation, sandier beds are thicker, very fine-grained, sub-angular, medium-sorted with a silty cement	½-11½
(15)	*sandy siltstone to silty sandstone*, quartzose, micaceous, dark brown to pinkish brown, iron-enriched and hardened with some development of iron-rich leaching structures, friable where not hardened as a result of iron-enrichment, thin-bedded, laminated with some colour-variegation, very fine-grained, sub-angular, medium-sorted, prominent brown silty cement, broad ripple marks poorly developed	11½-13
(14)	*silty sandstone to sandstone*, quartzose, micaceous, pale buff to whitish, in many places strongly ferruginised with remarkable development of iron-rich leaching structures in resistant ledges (these are secondary features, cylindrical, vertical, concretionary, often developing blisters on the under surfaces of beds), friable where fresh, probable broad ripple marks developed, bedding poorly expressed possibly thin-bedded, occasionally laminated, exhibiting gentle cross-lamination but little colour-variegation, very fine-grained, sub-angular, medium sorted, with abundant to minor silty cement. Rarely fossiliferous carrying vertebrate material	13-33
(13)	*sandstone*, quartzose, micaceous, pinkish brown to buff, some horizons are iron-enriched and hardened forming resistant ledges with prominent iron-rich leaching structures, incipient similar structures in other beds, friable where fresh, bedding obscure probably thin-bedded, indistinct laminations rare, very fine-grained, sub-angular, medium-sorted, minor silty cement. Rare plant material found in scree at this level also one piece of bone	33-48
(12)	*siltstone to silty sandstone*, quartzose, very slightly micaceous, brown to purplish brown, iron-enriched and hardened resistant ledges present with prominent iron-rich leaching structures, thin-bedded, occasionally laminated, with slight colour-variegation and gentle cross-lamination, very fine-grained, sub-angular with a brown silty cement	48-51¼
(11)	*silty shale to siltstone*, quartzose, micaceous, pale buff, mauve-tinted at base, grading to whitish grey with yellow-brown iron-mottling at top, friable, massive with one thin well-laminated band at 54½ ft., iron-rich leaching structures developing at top	51¼-56¾
(10)	*siltstone to sandy siltstone*, quartzose, micaceous, mauve colour with a dark yellow-brown iron-rich concretionary band 1 in. thick at 57¼ ft., friable, massive, sandier horizons are quartzose, sub-angular, with a dominant silty cement. Fossil vertebrate material found in situ	56¾-59¼
(9)	*silty shale*, quartzose, blue-grey when fresh, alters to purplish to dark brown due to iron-enrichment which has developed a resistant ledge in the upper 2 ft. and minor resistant bands below this including a thin, hard, purplish-red iron-rich concretionary band at 67½ ft., friable where weathered, where fresh has a conchoidal fracture, no bedding discernible in the fresh rock but thin-bedding and laminations, some displaying gentle cross-laminations, noted as it weathers. The ledge contains vertebrate material in place (second ledge)	59¼-71¼
(8)	*siltstone to silty sandstone*, quartzose, micaceous along bedding planes, fresh rock is pale buff to yellowish with yellowish streak, conchoidal fracture, but purplish to dark brown where iron-enriched, friable where weathered, thin-bedded and indistinctly laminated in part, very fine-grained, sub-angular, well-sorted with a buff coloured silty cement. A prominent resistant ledge (first	

ledge) hardened by iron-enrichment is developed between $71\frac{3}{4}$ ft. and $73\frac{1}{2}$ ft. the upper few inches of which contain abundant vertebrate material. This ledge has been prospected with success along much of its outcrop and quarried in the more promising localities (Quarry 1 and Quarry 2) .... $71\frac{1}{4}$-$76\frac{3}{4}$

(7) *shale to silty shale*, quartzose, slightly micaceous towards base, pale blue-green where fresh, but often strongly iron-stained yellow to yellow-brown, incipient iron-rich nodular and leaching structure zones common, friable where weathered, bedding indistinct, probably thin-bedded. Vertebrate material located in situ at $84\frac{1}{2}$ ft. associated with small yellowish acicular gypsum crystals. The locality has been quarried (Quarry 3). The first skull found was picked up on the talus slope just below this level. The third *Isaura* marker bed occurs at $81\frac{3}{4}$ ft. This bed is variable in thickness up to 3 in. These *Isaura* beds have a pitted weathered surface (due to removal of calcareous shell material) that enables them to be readily identified among the talus .... $76\frac{3}{4}$-87

(6) *silty shale*, quartzose, purplish-brown, with a reddish streak, thin-bedded, in part distinctly laminated with alternating light and dark laminae 87-89

(5) *shale to shaley siltstone*, quartzose, micaceous along bedding planes, buff colour, reddish streak, friable where weathered, thin-bedded (average thickness of beds at base $\frac{1}{2}$ in. thickening to 2 in. at top), in part laminated with slight colour-variegation. Thin iron-rich, purplish-red siltstone bands occur at $91\frac{1}{4}$ ft., $92\frac{1}{2}$ ft., and $93\frac{3}{4}$ ft. An *Isaura* bed occurs at $90\frac{3}{4}$ ft. below a 2 in. thick dark buff-coloured bed. At the top of the sequence a well-preserved plant specimen was found in situ 89-94

(4) *claystone to shale*, greenish-grey, conchoidal fracture with shiny fracture surfaces, greasy feel, slight earthy odour, massive generally but in part thin-bedded indistinctly. Band of hard dark brown iron-rich nodules, averaging 3 in. long and 1 in. thick at 97 ft. .... 94-$97\frac{1}{2}$

(3) *shaley siltstone to shale*, blue-grey to buff, friable where weathered, thin-bedded, fossiliferous. The first *Isaura* bed occurs at $99\frac{1}{4}$ ft., thickness varying up to $\frac{1}{2}$ in. Immediately above this, vertebrate material is found in situ associated with occasional *Isaura*-like fossils and lingulid brachiopods, and with small yellowish acicular gypsum crystals. Towards the top of the sequence a buff coloured harder band about 2 in. thick contains similar estheriids and brachiopods .... $97\frac{1}{2}$-100

(2) *silty shale to siltstone*, quartzose, micaceous, grey to buff, in part iron-stained, friable where weathered, thin-bedded, laminated exhibiting cross-laminations and colour-variegation, earthy odour at base. A thin discontinuous band of purplish iron-enriched siltstone occurs at the top of the sequence .... 100-$101\frac{3}{4}$

(1) *shale to silty shale*, pale greenish-grey, containing incipient iron-rich leaching structures, purplish-brown ferruginised zone at $102\frac{1}{2}$ ft., friable where weathered, thin-bedded in part laminated, becoming micaceous at top. Rare, clean, $\frac{1}{4}$ in. long quartz pods present, poorly cemented, very fine-grained, sub-angular, medium-sorted with dominantly frosted surface textures .... $101\frac{3}{4}$-104

It was noted throughout the section that weathering has accentuated features such as bedding, lamination, cross-lamination and colour-variegation which tend to disappear as the formation is quarried into. Features such as ripple marks are usually poorly defined, but one definite ripple-marked surface was disclosed at Locality 8 by careful quarrying.

In addition to the fossiliferous beds listed above at Locality 4, vertebrate material was found loose above Locality 7 on a saddle about 25 ft. below the Erskine Sandstone/Blina Shale contact, and in place at Locality 7 about 45 ft. below this contact (see Fig. 1). At Locality 6 an amphibian skull was found in the talus. The matrix of this skull was tentatively matched with rock in a ledge a few feet above the spot where the skull was found and about 60 ft. below the contact. And at Locality 8 where vertebrate material was quarried from a ledge about 60 ft. below the contact, rocks immediately below the contact itself contained bone in place. Other finds are marked on Fig. 1.

The other mapped areas of Blina Shale fall into three categories: those represented by bedded exposures, those represented by residual rubbles, and the breccia rims associated with the Fitzroy Volcanics at White Rocks and Wolgidee Hills. Brief descriptions of these areas are given in Tables I, II and III.

TABLE I.

Bedded Exposures.

Locality	Morphology	Lithology, Structure, Thickness	Fossils
Wongil Ridge Yeeda Station. 123° 45′ E., 17° 38′ 30″ S.	Low rise capped by laterite	Horizontal, micaceous, quartzose siltstones and very fine-grained sandstones, thin-bedded, laminated, variegated pale pink and yellowish	Plants, trails
Brennan's Bore Quanbun Station. 125° 12′ E., 18° 16′ 30″ S.	Two low mounds and dry well shaft	Uniform, blue-green, puggy fractured clay, 25′ thick	None found
North of Wolgidee Hills Noonkanbah Station. 125° 50′ 30″ E., 18° 16′ 30″ S.	Low mesa capped by laterite	Horizontal, micaceous, quartzose very fine-grained sandstone with abundant silty cement, thin-bedded, blue-grey to whitish grey. About 30′ thickness exposed	None found
$1\frac{1}{2}$ miles ENE Bore 20 Noonkanbah Station. 124° 47′ 30″ E., 18° 10′ 30″ S.	Low rounded hill	Rubbly outcrop. Quarrying should disclose fossiliferous strata. New locality for Blina Shale	Amphibian remains, fish scales.
Bore 20 Noonkanbah Station. 126° 46′ E., 18° 11′ S.	Bore section	Puggy, blue-grey clay	Fossil plants and "insects" (Wade 1936 via Guppy 1958)

TABLE II.

Residual Rubbles.

Locality	Morphology	Lithology, Structure, Thickness	Fossils
Between Bannan's and Mimosa Bores, Blina Station. 124° 32′ E., 17° 40′ S.	Slight topographic rise	Ferruginised rubble of yellow-brown to brown, micaceous, quartzose, very fine-grained, sub-angular, medium-sorted sandstone with a silty cement	One fragment of amphibian bone found
Ryan's Bore, Blina Station. 124° 28′ 30″ E., 17° 44′ 30″ S.	Level plain	Dark greenish-yellow soil containing pale brown gypsum crystals, occasional ferruginised siltstone rubble	None found
SE of Telephone Dam, Kimberley Downs Station. 124° 20′ E., 17° 28′ S.	Level plain	Three small patches of ferruginised rubble	None found
NW of Willumbah, Liveringa Station. 124° 15′ E., 17° 56′ S. and 124° 15′ E., 17° 57′ S.	Low rise	Ferruginised conglomerate overlying the Permian Liveringa Formation	None found
Across track between Erskine's Well and Boab Tank, Liveringa Station. 124° 20′ E., 17° 54′ S.	Level plain	Dark greenish-yellow soil, occasional ferruginised rubble	None found
Boab Tank, Liveringa Station. 124° 17′ E., 17° 53′ S.	Level plain, excavated tank	Yellow-brown, vaguely bedded, slightly cross-bedded and laminated, fine-grained, sub-angular, well-sorted, micaceous quartz sandstone with minor cement. Probably belongs to Erskine Sandstone	Trails (?)
One mile S. of Egan's Bore, Paradise Station. 124° 33′ E., 17° 57′ 30″ S.	Level plain	Rubble of flattish boulders consisting of dark brown cobble conglomerate with a matrix of fine-grained calcarenite having a silty cement	*Isaura*, amphibian bone fragments including clavicle
Dry Corner area, Nerrima Station. 124° 05′ 30″ E., 18° 21′ S.	Generally flat with low rises	Synclinal area. Ferruginised conglomerate and rubble. But note that Bureau of Mineral Resources geologists collected amphibian material from here described by Brunnschweiler (1954). The joint Museum expedition unfortunately could not re-establish the locality although some days were spent in the area	*Lingula*, *Isaura*, amphibian remains, fish scales (Brunnschweiler 1954)
Bore 6 Noonkanbah Station. 124° 45′ E., 18° 20′ S.	Level plain	Dark greenish-yellow soil containing gypsum crystals, occasional rubble	One fragment of amphibian bone
Jubilee Dam, Quanbun Station (= Alligator Dam, Guppy *et al* 1958, = a tank on Quanbun Station, Glauert 1921). 124° 14′ E., 18° 18′ 30″ S.	Excavated dam	Soil contains gypsum crystals	Pleistocene crocodilian remains (Glauert 1921, 1926)

TABLE III.

Breccia Rims.

Locality	Morphology	Lithology, Structure, Thickness	Fossils
White Rocks, Noonkanbah Station. 124° 46′ E., 18° 12′ S.	Breccia rim of the Fitzroy Volcanics	Country rocks have been brecciated, metamorphosed, stained green, re-cemented and hardened as a result of intrusion by lamproite bodies	None found
Wolgidee Hills, Noonkanbah Station. 124° 51′ 30″ E., 18° 19′ S.	As above	Lithology as above. New locality. Note that in August 1955, Prider noted the presence of a dark green hornfelsed shale in this area (Professor R. T. Prider, personal communication) and sampled this shale (Geology Department, University of Western Australia, Sample No. 42615)	*Isaura*, a bone fragment, a few large pieces of fossilised wood and several small ones collected. Sample No. 42615 is *Isaura*-rich

The only area not visited by the party was the large area, tentatively mapped as Blina Shale, south-west of Halls Creek. As the region is not easily accessible and the correlation was known to be tentative (R. M. L. Elliott, personal communication) it was felt that a trip there was not justified in view of the heavy demands it would make on the party and the probable lack of success that would result.

The Erskine Sandstone

The Erskine Sandstone at Erskine Range was examined in less detail than the Blina Shale.

Plant collections were made from the Erskine Sandstone at Locality 5, Erskine Range, from The Sisters Plateau and from Yarrada Hill, but no attempt was made to locate these collections stratigraphically in the sequence described below.

Boulders of Meda Formation	Thickness Feet
(3) *sandstone*, quartzose, whitish, iron-stained yellow-brown to purplish-pink, friable to crumbly, thick-bedded becoming thin-bedded at the top, strongly cross-bedded, laminated with marked colour-variegation and cross-lamination, extensively ripple-marked even on cross-bedded surfaces, mud-cracked, fine-grained, sub-angular, medium-sorted, with dominantly frosted surface textures and minor cement. Locally micaceous	About 30

(2) *sandy siltstone*, quartzose, slightly micaceous, whitish, thick-bedded, cross-bedded, laminated with colour-variegation, whitish silty cement. The basal bed is ripple-marked, while the uppermost bed is mud-cracked. The unit includes a lens of medium-grained quartzose sandstone, cross-bedded, with prominent silt pellet horizons. The enclosing surfaces of this lens are thin purplish ferruginous siltstone bands which are ripple-marked 30-36½

(1) *sandstone*, quartzose, micaceous, friable to crumbly, whitish to creamy, medium to thick-bedded, strongly cross-bedded, laminated and gently cross-laminated with some colour-variegation, carrying rare silt pellets, fine-grained to very fine-grained, sub-angular, medium-sorted, with dominantly frosted surface textures. Two feet below the top is a 1 in. thick purplish ferruginised siltstone band associated with rich silt pellet horizons. At the top of the sequence is a similar siltstone band 36½-58½

Contact with the Blina Shale.

Mapping at Localities 4, 6, 7 and 8, disclosed that the contact between the Erskine Sandstone and the Blina Shale is a disconformity (see Table IV). The time break is probably a small one, being represented by the thin ferruginised siltstone described.

TABLE IV

Heights of the Erskine Sandstone/Blina Shale contact, with respect to Locality 4, corrected for dip of the Blina Shale, to show that the contact is a disconformity.

Locality	Height a.s.l. ft.	Height w.r.t. Locality 4 corrected for dip ft.
At Locality 4	317.22	0.00
At Locality 7	322.20	+ 4.98
At Locality 6	326.40	+17.03
At Locality 8	307.65	+ 4.18
NE of Locality 8	295.65	+ 2.13
NE of Locality 8	304.50	+16.21

Brunnschweiler (1954) has assigned the Erskine Sandstone to the Upper Triassic. On the basis of the microflora, however, Balme considers that the Erskine Sandstone is probably Lower Triassic in age (B. E. Balme, personal communication). Both the Blina Shale and the Erskine Sandstone, therefore, probably belong in the Lower Triassic rather than the Upper Triassic as suggested by Brunnschweiler.

At The Sisters Plateau plant locality the Erskine Sandstone is a quartzose, micaceous, carbonaceous, grey, thin-bedded silty sandstone. Pieces of plant stems are commonly preserved with rare leaf impressions. Both were collected.

Eighty-one measurements of the attitudes of cross-beddings in the Erskine Sandstone at Erskine Range were made and the poles of the measurements later plotted on a polar equal-area net. It can be inferred from the plot that the ancient river responsible for the deposition of the Erskine Sandstone flowed northwards in this area (Fig. 2).

Environment of Deposition of the Blina Shale

Brunnschweiler (1954) has suggested that the environment of the Blina Shale may be described as "lagoonal or in parts estuarine". It is difficult to reconcile the evidence with either of these postulates.

Shoreline lagoons are generally linear and fronted by barrier bars or beaches. Currents sweep through them so that channels and flats within the lagoon are well defined, linear and broadly parallel to the shoreline. The outcrop pattern of the Blina Shale, however, is not linear but indicates that the environment was basinal. The lithology of the formation is remarkably uniform both laterally and vertically. No evidence is known for the presence of intraformational, contemporaneous bars and/or beaches. It is unlikely that the facies was lagoonal in the strict sense.

In estuarine environments the sea dominates, i.e., tidal currents are more effective than river currents in distributing the accumulated sediment. Channels and flats form but are constantly reworked. It is difficult to envisage the *Isaura* coquinoidal beds developing, and entire jaws of vertebrate animals being preserved, in an environment as active as the river estuary.

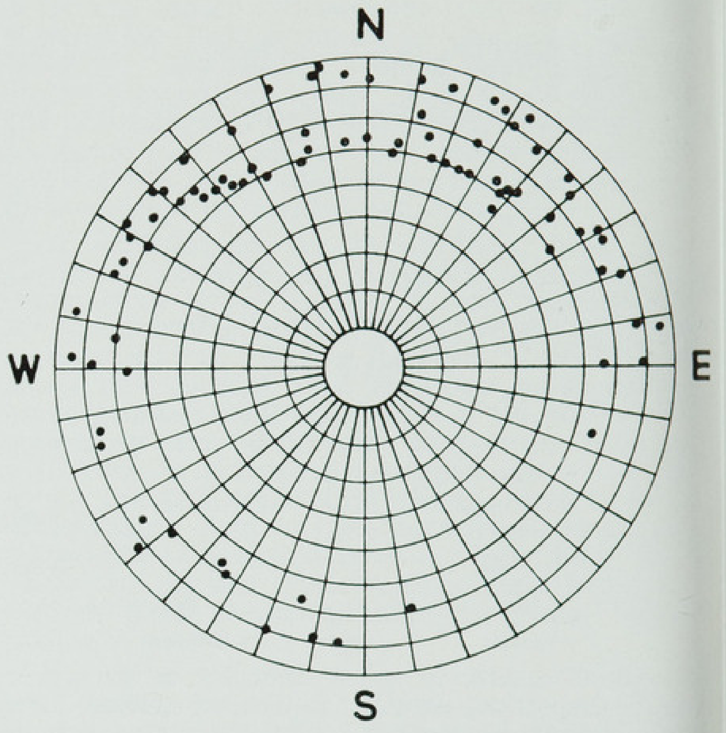

Fig. 2.—Poles of eighty-one cross-beddings in the Erskine Sandstone at Erskine Range plotted on a polar equal area net.

The author considers that the Blina Shale was deposited, during a period of intermittent subsidence, in a wide, shallow, gently shelving, quiet gulf or sea into which protruded the delta of a major river. The beds exposed at Erskine Range were probably deposited near-shore on the subaqueous topset plain of this delta.

The high iron content of the sediment is indicated by the iron-rich leaching structures in all stages of development, by the reddish streak of yellow and buff-coloured oxidised beds, by bands of nodular ironstone, and by the blue-grey colour of the fresh rock which probably derives from its ferrous iron content. It is highly likely that these iron-rich sediments were ferruginous in origin, their iron content resulting from the breakdown of rocks through subaerial weathering. This indicates near-shore deposition.

The grade of the sediments constituting the Blina Shale at Erskine Range (almost invariably very fine-grained to silty), their shape (sub-angular), their degree of sorting (moderate) and the high percentage of quartz point to comparatively near-shore deposition with a fairly rapid inflow.

Shallow-water deposition best explains the linear ripple marks exposed at Locality 8 where several entire lower jaws of fossil amphibia were quarried from the ripple-marked surface.

Features such as thin-bedding, lamination, cross-lamination and colour-variegation between laminae are visible on weathered surfaces. Such features are known to characterise present-day deltaic environments (Shepard and Lankford 1959).

It may be expected that silt banks were built up in front of the delta shoreface to the point where they became exposed. The several thin discontinuous bands of ferruginised, purplish siltstone, that occur in the sequence examined may well express this phase of the sedimentation cycle. Their subsequent overlap by blue-grey silts indicates that subsidence was intermittent during deposition of the Blina Shale.

Balme considers that the richness of the microplankton suite and spore-pollen assemblages suggests a shallow-water near-shore marine environment of deposition for the Blina Shale (B. E. Balme, personal communication). His data came from various bores in the Fitzroy Trough, the nearest of which is about nineteen miles north of Erskine Range. The general lithology of the Blina Shale in these bores, however, is similar to that exposed in the same formation at Erskine Range and the evidence from Balme's data may usefully be correlated with the palaeoecological implications of the fauna and flora collected at Erskine Range.

The presence of only occasional plant fossils in the Blina Shale at Erskine Range suggests near-shore marine deposition as opposed to deposition in a vegetated shoreline swamp or lagoon with vegetated shores.

The faunal assemblage at Erskine Range is of especial significance in determining the environment. Thin, coquinoidal beds of *Isaura* are associated with occasional shells of *Lingula*, with the remains of presumably continental fossil amphibia and with fish remains. *Isaura* has fresh-water and brackish-water affinities (Piveteau 1953) while *Lingula* is a marine mud-dweller of wide tolerances. Assuming the ancient amphibians were continental, they may have lived on the subaerial delta and their remains could have been carried downstream, not necessarily any great distance, accumulating on the subaqueous topset plain and in inshore pockets once they reached the sea. This could explain why no entire vertebrate animals were found, although occasional articulated remains were collected. Dipnoan teeth were among the identifiable fish remains. Living descendants of these ancient fish are exclusively fresh-water.

The sedimentary characters of the Blina Shale, the presence of only occasional plant remains, although these are usually well preserved, the microplankton suite and the occurrence of *Lingula* indicate that the formation accumulated by deposition on the topset plain of the marine delta of a major river. But the rare articulated remains of the vertebrate fauna with its fresh-water affinities and the *Isaura* fauna, present certain anomalous features which only further work can clarify. It is noted, however, that *Isaura* has marine associations in the Upper Triassic of Germany, and that trematosaurid amphibians occur together with ammonites in the marine Lower Triassic of Greenland (Termier and Termier 1960).

The period of intermittent subsidence during which the Blina Shale was deposited gradually gave way to a regressive phase in which the marine deltaic beds of the Blina Shale at Erskine Range were overlapped by the sandier, cross-bedded, river channel sediments of the Erskine Sandstone with its rich flora. The disconformity between the Blina Shale and the Erskine Sandstone represents the transitional period between these transgressive and regressive phases.

Conclusion

It is hoped that the interest aroused by the joint Museum expedition to the Fitzroy Trough will stimulate further work on this important Triassic unit, the Blina Shale. Balme has recognised a probable equivalent to the Blina Shale in B.M.R. Wallal 44A Bore in the southern part of the Canning Basin where no Triassic has previously been recorded (B. E. Balme, personal communication). Triassic rocks in the Canning Basin, therefore, have a much wider distribution than was hitherto thought.

The importance of this Triassic verterbrate assemblage in the Australian record, with the opportunities it affords for correlation on a world-wide scale, cannot be too highly stressed.

The vertebrate localities have scarcely been touched and good collections will undoubtedly reward future search. One of the objectives of this paper has been to give descriptions of the localities from which vertebrate fossils were obtained by the expedition and to direct future searchers to the most rewarding exposures so that valuable field time is not wasted in unrewarding areas.

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