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An Appraisal of the New England Geosyncline for Phosphate

by

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SUMMARY

The rock provinces of the New England area, northern New South Wales, represent phases of geosynclinal-type sedimentation and in general cannot be regarded as prospective for phosphorite. However, periods of chemical sedimentation represented by cherts, with associated limestones, shales and minor sandstones occur in the Yarrimie Formation (Middle Devonian) of the Tamworth Group. A field reconnaissance of the Yarrimie Formation in the Tamworth-Nundle area failed to locate significant phosphates.

Cherts are also common in some sequences in the Central Complex, and although the dominance of thick clastics with minor volcanics, and the complex structures, are unfavourable for the occurrence of economic deposits of phosphate, further investigation of these areas is recommended.

INTRODUCTION

The New England area, which comprises the north-eastern part of New South Wales, is represented on the Inverell, Grafton, Manilla, Dorrigo, Tamworth and Hastings 1:250,000 topographic sheets (Royal Australian Survey Corps). Geological maps of the area include the New England Tablelands (Southern Part) 1:250,000 (Binns, et. al., 1967); Gravesend 1:100,000 (McKelvey and Yeates, 1970 in prep); Bangheet 1:100,000 (McKelvey, 1968); Horton 1:100,000 (McKelvey and White, 1964); Tareela 1:100,000 (White, 1965); Boggabri 1:100,000 (Voisey, 1964); Gunnedah 1:100,000 (Manser, 1965a); Curlewis 1:100,000 (Manser, 1965b); Wingen 1:100,000 (Manser, 1968); Attunga 1:100,000 (White, 1964a); and Tamworth 1:100,000 (White, 1964b). The N.S.W. Mines Department has also published the Dorrigo 1:250,000 sheet.

Other studies in New England such as those Chappell (1961), Crook (1961a, 1961b), and McKelvey and Gutsche (1969) have been confined to more detail in specific areas, and there is a considerable amount of more recent data as yet unpublished.

THE NEW ENGLAND GEOSYNCLINE

The New England Geosyncline (Ordovician to Permian) consists dominantly of volcanic derived sedimentary rocks. It is one of the large elongate basins of deposition within the Tasman Geosyncline. The New England Geosyncline is overlain in the west and the north-west by terrestrial sedimentary rocks of the Great Artesian Basin and in the north-east by other terrestrial rocks of the Mesozoic Clarence-Moreton Basin. The southern-most outcrops of the New England Geosyncline occur immediately north and north-east of the unconformably overlying Permo-Triassic Sydney Basin (see Fig. 1). The younger Sydney and Great Artesian Basins, which are horizontally bedded, obscure the relationship of the New England Geosyncline with the older Lachlan Geosyncline to the west.

Voisey (1959) sub-divided the New England Geosyncline into the tectonic provinces shown in Figure 2. His sub-division, though in need of revision, is widely recognised and his nomenclature is used here. Voisey distinguished the Great Serpentine Belt, which follows the Peel Thrust, as separating the Devonian to Permian Rocks of the Western Belt of Folds and Thrusts and the Basin and Dome Belts from the "lower Palaeozoic" (now known to be mainly Permian) Central Complex. The Central Complex is intruded by the New England Granite Batholith (see Fig. 2). The Eastern Belt of Folds and Thrusts and the Upthrust Blocks occupy eastern New England.

The Western Belt of Folds and Thrusts

The Western Belt of Folds and Thrusts (Voisey, 1959), which parallels the Peel and Hunter-Mooki thrusts, is bounded in the east for most of its length by the Great Serpentine Belt, which follows the Peel thrust. It is separated from Permian sedimentary rocks and lavas to the west by the Hunter-Mooki thrust system which probably continues into Queensland as the Goondiwindi Fault (Runnegar, 1970). It continues southwards as the Basin Belt and Dome Belt (Voisey, 1959 p. 194: see Fig. 2, this report). Averaging 55 km in width and some 350 km in length, it is characterised by a series of meridional folds and faults. Deformation across the belt increases from the broad, open, gently plunging folds and oblique slip faults in the west to the isoclinal folding and more intense faulting recognised and described near the Peel Fault in the east (Chappell, 1959; Price, 1970).

The stratigraphy of this province is well known, especially in the west towards the inferred position of the source area. However, in some areas near the Peel Fault complexities in the stratigraphy arise. Some lithologic units lose their identity through facies changes, and the absence of fossils, the isoclinal folding, and the complex faulting adjacent to the Peel Fault all tend to obscure the succession of litho-stratigraphic units.

The stratigraphic nomenclature, which has been considerably refined since the early work of Benson (1913 - 1917) and Carey and Brown (1938), is that of McKelvey (1966) White (1966) Roberts (1961) and Crook (1961) in part. (see also, McKelvey 1968; McKelvey and White, 1964; and White, 1964; 1965). Their sub-divisions which are currently in use and widely recognised, are shown in Table 1.

The oldest rocks exposed belong to the Tamworth Group, which consists of an association which may loosely be termed early geosynclinal. Lithologies present include basic lavas, dolerites, cherts, shales, and limestones, in addition to medium- and coarse-grained detrital sedimentary rocks. The abundance of chert in the Yarrimie Formation indicates a significant period of chemical sedimentation. The overlying marine rocks consist dominantly of volcanic derived, detrital, sedimentary rocks of a wide range in grain size, occasional basic lavas, and limestones. This association is overlain by the dominantly terrestrial piedmont sediments and interbedded pyroclastics of Carboniferous age, which are referred to as the Kuttung Group.

The broad palaeogeography represented by the Western Belt of Folds and Thrusts is fairly well known. There is complete agreement that the source area for the sedimentary rocks lay to the west, and that it was somewhat linear in nature and characterised by volcanism. However it is not known whether or not the sequence was derived from an island arc or a linear continental margin. The lithologies of the Western Belt of Folds and Thrusts appear to be mainly shallow water in nature. The abundance of mudstones merely reflects periods of low energy sedimentation in shallow water, rather than deep water sedimentation. The mudstones are often interbedded with laterally persistent, sheet deposits of bioclastic and oolitic limestones, as well as sandstones.

Significant disconformities occur in the shallow marine sequences towards the (western) source area, and in such environments condensed sequences are to be expected.

Basin and Dome Belts

The Basin Belt and Dome Belt which occur south of the Western Belt of Folds and Thrusts (see Fig. 2) were so named from their structural styles by Voisey (1959, p. 195). Lithologies described by Sussmilch and David (1919) Osborne (1922 p. 161-162) and Roberts (1961) from this area, resemble those of the volcanic and volcanic derived sedimentary rocks of the Western Belt of Folds and Thrust and they can be regarded as their lithostratigraphic equivalents in part. Roberts (1961, p. 86) described the palaeogeographic setting of this area and deduced that shallow water marine conditions of sedimentation occurred during the Carboniferous. Thus the Dome and Basin Belts can be regarded broadly as a southern extension of the Western Belt of Folds and Thrusts during Carboniferous time. However, Roberts has found marine intercalations in some terrestrial sequences (Kutting Group) exposed in the Hunter Valley (pers. comm., 1970). This is not known further to the north.

The Central Complex

The Central Complex occupies a wide area east of the Peel Fault. The stratigraphy is not well known because of the absence of regionally persistent marker horizons, scarcity of fossil remains, and complex structural relationships.

However three different lithological associations within this province, have been recognized (Binns et al 1967). The first consists of a steeply dipping sequence of greywackes, siltstones, slates, laminated cherts, jaspers and localised occurrences of basic lavas exposed immediately east of the Peel Fault from Nundle to Danglemah and also north-east of Armidale. The second lithologic association occurs further east; it is also of geosynclinal character and consists of similar rocks, except for chert and jasper, which are lacking. The third assemblage crops out near Armidale and comprises horizontally bedded Permian terrestrial conglomerates, siltstones, and mudstone, with acid lavas and pyroclastics (McKelvey and Gutsche, 1969).

In the Central Complex the immense volume of detrital sedimentary rocks (greywackes, siltstones and slates) show many features characteristic of turbidite sequences in contrast with the dominantly non-turbidite sedimentary rocks of the Western Belt of Folds and Thrusts.

This fact together with the different facies and rock types in the Western Belt of Folds and Thrusts suggest that a barrier existed between the two areas during perhaps Upper Devonian, Carboniferous and pre-orogenic Permian times. Price (1970) established the presence of such a structure for at least the Upper Carboniferous and Lower Premian in the Woodsreef area near Barraba. This "barrier" later became a site of thrust faulting along which the Peel Fault developed.

All the detrital rocks have a volcanic omponent, and this feature, together with occurrences of basic lavas, suggests the cherts and jaspers are of volcanic derivation in part. Some are known to contain radiolarians, but most are composed of inorganic silica. Thus, it is likely that the cherts and jaspers have no palaeogeographic significance and that their distribution was controlled by the chemistry of the environment of deposition rather than by the physiography of that environment.

Eastern Belt of Folds and Thrusts and the Upthrust Blocks

The Eastern Belt of Folds and Thrusts and the Upthrust Blocks occupy the eastern part of the New England geosyncline. Little detailed work has been carried out in these areas, and reports on the geology are restricted mainly to Voisey's (1934, 1936, 1938, 1939 and 1959) regional descriptions.

The Palaeozoic sequences of the Eastern Belt of Folds and Thrusts resemble those already described from the Western Belt of Folds and Thrusts and the Central Complex,and Voisey has correlated them with these.

The Upthrust Blocks, which are bounded by transcurrent faults and some outcrops of serpentinite, consist mainly of intensely folded phyllites, slates, cherts and quartzites, some of which may be lithostratigraphic equivalents of the Woolomin Beds exposed in the Central Complex (Voisey, 1934).

The New England Granite Batholith

The intrusive granitic rocks of New England, lie within the Central Complex midway between two serpentinite belts (Voisey, 1959 p. 196). They comprise two distinct suites distinguishable in the field, and by their microscopic characteristics (Binns et al, 1967). The older granites belong to the Hillgrove Plutonic Suite and crop out in a northerly trending belt in eastern New England. They are generally foliated, elongate and have been emplaced under stress conditions.

Unstressed intrusions, grouped by Binns et. al. (1967) as the New England Batholith, are massive and surrounded by prominent contact aureoles of hornfels where they intrude sedimentary rocks. Age relationships between adjacent granites indicate that they are a series of sequential intrusions. The most common rock types are granodiorite and adamellite, with very minor marginal phases of diorite and gabbro.

Tertiary Gravels and Basalts

In many localities, the Palaeozoic rocks of the New England area are overlain by thin, Tertiary river gravels and alkali olivine basalts, which form a plateau-like landscape. The river gravels are poorly consolidated ferruginous conglomerates and sandstones, which often contain abundant plant remains.

ORIGIN OF MARINE SEDIMENTARY PHOSPHORITES

Most marine phosphates are associated with chemical and/or biochemical sedimentation in areas characterised by tectonic stability. The classic occurrence of this nature is the Permian Phosphoria Formation of the U.S.A. (McKelvey et al, 1953) which is associated with thin sequences of dark shales and cherts which pass laterally into carbonates and red beds. The environment of deposition reasoned for this deposit is between a shallow marine platform and the open sea. Such occurrences are formed from up-welling ocean currents although there is still no general agreement on the precise conditions controlling the precipitation of phosphate. Sheldon (1966) has suggested that phosphorite deposits are restricted to the belts between the 5° and 40° parallels of latitude. Their association with condensed sequences and disconformities is well established. Though frequently restricted stratigraphically and associated with chemically deposited limestones, biogenic cherts and carbonaceous shales, phosphorite deposits may be formed in both geosynclinal or platform environments (Carozzi, 1960).

Examples of probable platform phosphorites in Australia include those of the Amadeus Basin (Cook, 1963) and the major deposits of the Georgina Basin (De Keyser and McLeod, 1968; Russell, 1968). Minor deposits occur in the lower Palaeozoic chert/slate association from the Tasman Geosyncline of south-eastern Australia (Sheldon, 1966; Jones, 1966) and as similar geosynclinal sequences are present in a large part of New England, there is a possibility that deposits may occur there also.

PROSPECTING GUIDE

The search for phosphate requires an appraisal of the stratigraphy of the area with the object of identifying sequences of dominantly chemical sedimentary rocks deposited in a suitable palaeo-environment. In view of the uncertainties surrounding phosphogenic environments, and the difficulties inherent in palaeogeographic reconstruction, the palaeo-environmental approach must be used with caution. However, the association of phosphorites with condensed sequences of cherts and shales, and often carbonates, is well established and a close examination of formations of this type must form the basis of any prospecting programme.

Altschuler, et al (1955) have noted that trace amounts of uranium may replace calcium in the apatite structure and many phosphorites have a uranium content significantly higher than other sediments. Therefore, a scintillometer survey can be used as an indirect method of locating phosphorites.

As primary phosphate-bearing minerals are hard to identify in the field, they can easily escape recognition. For this reason, it is necessary to carry chemical spot tests in the field. These can be made following the procedure outlined by Shapiro (1952).

ASSESSMENT OF THE POTENTIAL OF THE NEW ENGLAND AREA FOR PHOSPHATE

From the brief outline of the geology of New England given above, it is clear that the prospects of finding large deposits of phosphorite are not encouraging owing to the dominance of geosynclinal type deposits in the region. Many of the sedimentary rocks are volcanic derived and clearly, major phosphate occurrences are unlikely in such settings. However, Gibson (1967) has reported a volcanic contribution (including glass shards, volcanic ash and zeolites) in the phosphatic strata of North Carolina. This occurrence indicates that a volcanic setting should not be ruled out entirely.

The Tamworth Group, the oldest rocks exposed in the Western Belt of Folds and Thrusts,are considered to be early geosynclinal on the basis of their basic lava-dolerite-chert shale association with greywackes and limestones. Part of this association contains the right rock types to search for phosphate. These rocks, which are exposed in the Attunga-Tamworth-Nundle area, are considered to have formed some distance off-shore because they occur in the east of a tectonic province whose source area lay to the west.

Crook (1961a) who mapped their distribution in the Tamworth-Nundle Area, has sub-divided them as follows:

TAMWORTH LOWER GROUP	MIDDLE DEVONIAN	Yarrimie Formation 884 m. Chert, cherty argillite minor greywacke and mudstones. Moore Creek Member: biohermal, coralline limestone, Crawney Limestone Member: crinoidal limestone Levy Greywacke Member: greywacke, argillite.
		Silver Gully Formation 701 m. Arenites and rudites. Loomberah Limestone Member: brecciated biohermal limestone
	DEVONIAN	Wogarda Argillite 107 m. Cherty argillite, fine greywacke.
		Drik-Drik Formation 792 m. Arenites, breccias, limestone. Nemingha Limestone Member: bichermal, coralline limestone.
		Copes Creek Keratophyre 305 m. Keratophyre
		Pipeclay Creek Formation 609+ m. Black argillite, greywacke.
		Seven Mile Formation 1036 m. Black and white banded argillites, greywacke and limestone lenses.
		Hawk's Nest Beds (thickness unknown). Pyritic shale, greywackes

No complete sections are known in the Tamworth Group as its base is not exposed and the oblique slip faulting has caused displacement of units and repetition of lithologies.

The Yarrimie Formation, which contains mainly chemically (biogenic in part) deposited cherts, is on a lithologic basis the most suitable stratigraphic unit for the occurrence of phosphate in New England. It consists dominantly of banded black, grey and greenish chert and pyritic chert with white bands of radiolarian chert (Crook, 1961a). Other rock types include argillaceous cherts, occasional beds of greywacke, small beds of limestone; higher in the sequence the cherts pass with gradational contact into shales of the Baldwin Formation (Crook, 1961a).

A short reconnaissance for phosphate was carried out in the Tamworth-Nundle area over the outcrops of the Yarrimie Formation. Crook's (1961a) maps were followed and sections exposed in road cuttings and creeks were examined.

Features of the rock types noted in the Yarrimie Formation were the lateral persistence of thin laminae, the abundance of cherty rocks and the absence of any current structures in some of the interbedded sandstones. These sandstones, which display well developed graded bedding, always have a sharply defined base where they overlie fine grained rocks and show no evidence of erosion, sole markings or current bedding. The sandstones, are composed of volcanic detritus and most of them may represent sub-marine ash-fall deposits from volcanic eruptions rather than turbidite deposits. Some of the interbedded sandstones, however, do contain partly rounded mudstone fragments and other features suggestive of density current deposits. In contrast with the rapid clastic seminentation indicated by the sandstone units, the large thicknesses of cherty rocks indicate long periods of stability in the environment.

All rock types examined in the Yarrimie Formation were subjected to spot testing in the field with the ammonium molybdate reagent on fresh surfaces. When applied to cherts, the light coloured bands generally gave positive results, and some sandstones yielded positive results also. Certain limestones gave positive results. However, this could have been due to small amounts of apatite in the form of conodonts or possibly fish teeth or bones, which are known to be present in some limestones. One specimen of dolerite also gave a positive reaction.

All specimens which gave positive results with the molybdate spot testing reagent were subjected to semi-quantitative analysis for P_2O_5 using the method devised by Shapiro (1952). No analyses exceeding 1 percent were recorded. This portrays the highly sensitive nature of the ammonium molybdate solution. It is perhaps too sensitive for field work.

As stated earlier the palaeogeography of the Central Complex is not known with any degree of precision. Banded cherts, massive cherts, brecciated cherts and slates do exist in this sequence and a limestone, the Yessabah limestone does crop out west of Kempsey. However, many cherts are argillaceous indicating contemporaneous precipitation of silica and detrital sedimentation from suspension currents. Because the cherts (and jaspers) are interbedded with volcanic derived (in part) sedimentary rocks and occasional lavas, and their inorganic component often exceeds their organic component, it is reasonable to assume that these siliceous rocks have been formed by precipitation of silica on the sea-floor from volcanic hot springs emanating from fractures or faults. Radiolarians probably flourished in the silica rich environment rather than caused it.

Even though the cherts are interbedded with a large thickness of sedimentary rocks, they do record significant periods of almost non-detrital sedimentation, indicating the pulsatory nature of epiclastic sedimentation. For this reason, any phosphorites in the Central Complex could only concentrate in periods of non-deposition and hence would be associated with cherts. Even so, any phosphate precipitated may be diluted by contemporaneous precipitation of silica, assuming the silica was derived from sea-floor hot springs.

CONCLUSIONS

The only stratigraphic unit in the Western Belt of Folds and Thrusts likely to contain phosphorite is the Yarrimie Formation, which outcrops in the Tamworth-Nundle area. A reconnaissance of this area failed to locate concentrations of phosphate. As no chemical sedimentary rocks have been found associated with disconformities in the condensed sequences on the western (shoreward) side of the Western Belt of Folds and Thrusts, there is little chance of finding phosphorites associated with a disconformity.

In the Central Complex, the only likely occurrence of phosphorite would be associated with a significant diastem or directly with cherts. Cherts are widely distributed in the Central Complex and an examination of these rocks should be carried out. However, dips are generally steep and this constitutes another unfavourable factor in finding a large accessible deposit.

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TABLE 1

COMPARISM AND APPROXIMATE LITHOSTRATIGRAPHIC CORRELATION OF SEQUENCES IN THE BANGHEET/HORTON AREA AND TAMWORTH AREA (WESTERN BELT OF FOLDS AND THRUSTS) WITH A SEQUENCE NEAR SCONE (BELT OF DOMES AND BASINS)

AGE		BANGHEET,HORTON DISTRICT (McDelvey, 1966; White, 1966)		TAMWORTH DISTRICT (Crook, 1961; Voisey and Williams, 1964; White, 1964)		GRESFORD DISTRICT (Roberts, 1961)	
CARBONIFEROUS	KUTTUNG GROUP	Lark Hill Formation	KUTTUNG GROUP	Currabubula Formation	KUTTUNG GROUP	Glacial Stage	Flagstaff Sandstone
		Rocky Creek Conglomerate					
		Clifden Formation				Mt.Johnson Beds	
		Ermelo Dacite Tuff				Gilmore Volcanics	
		Spion Kop Conglomerate		Coepolly Conglomerate		Wallaringa Formation	
		Caroda Formation		Merlewood Formation			Bonnington Formation
		Namoi Formation	BURINDI GROUP	Namoi Formation	BURINDI GROUP	Ararat Formation	
		Luton Formation		Tulcumba Sandstone		Bingleburra Formation	
DEVONIAN				Tangaratta Formation		not exposed	
		Mandowa Mudstone		Mandowa Mudstone			
		Keepit Conglomerate		Keepit Conglomerate			
		Eungai Mudstone		Baldwin Formation			
		Lowana Formation					
		Noumea Beds					
		base not known		Tamworth Group			

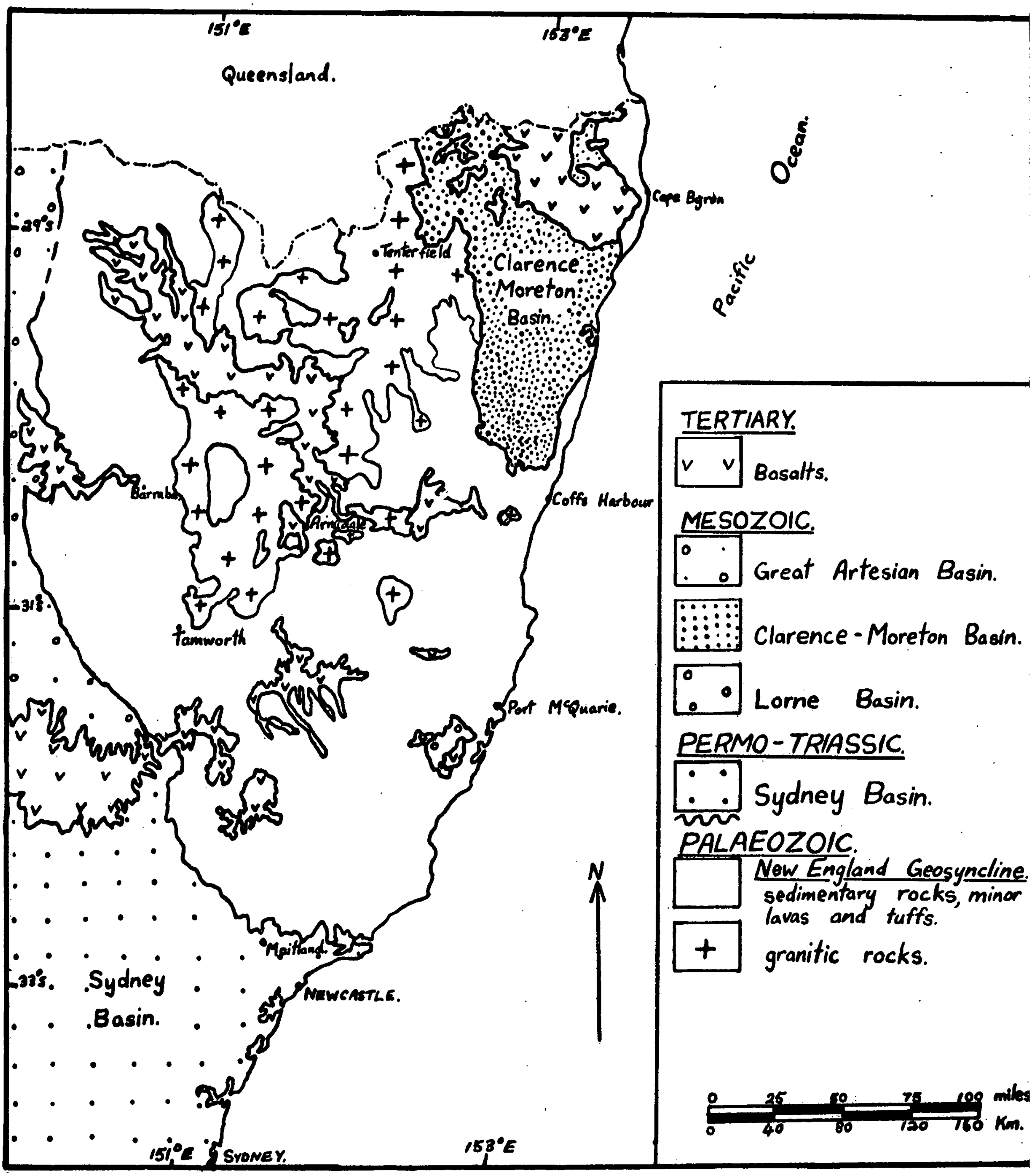

Fig. 1. Map showing location of the New England Geosyncline in north-eastern New South Wales.

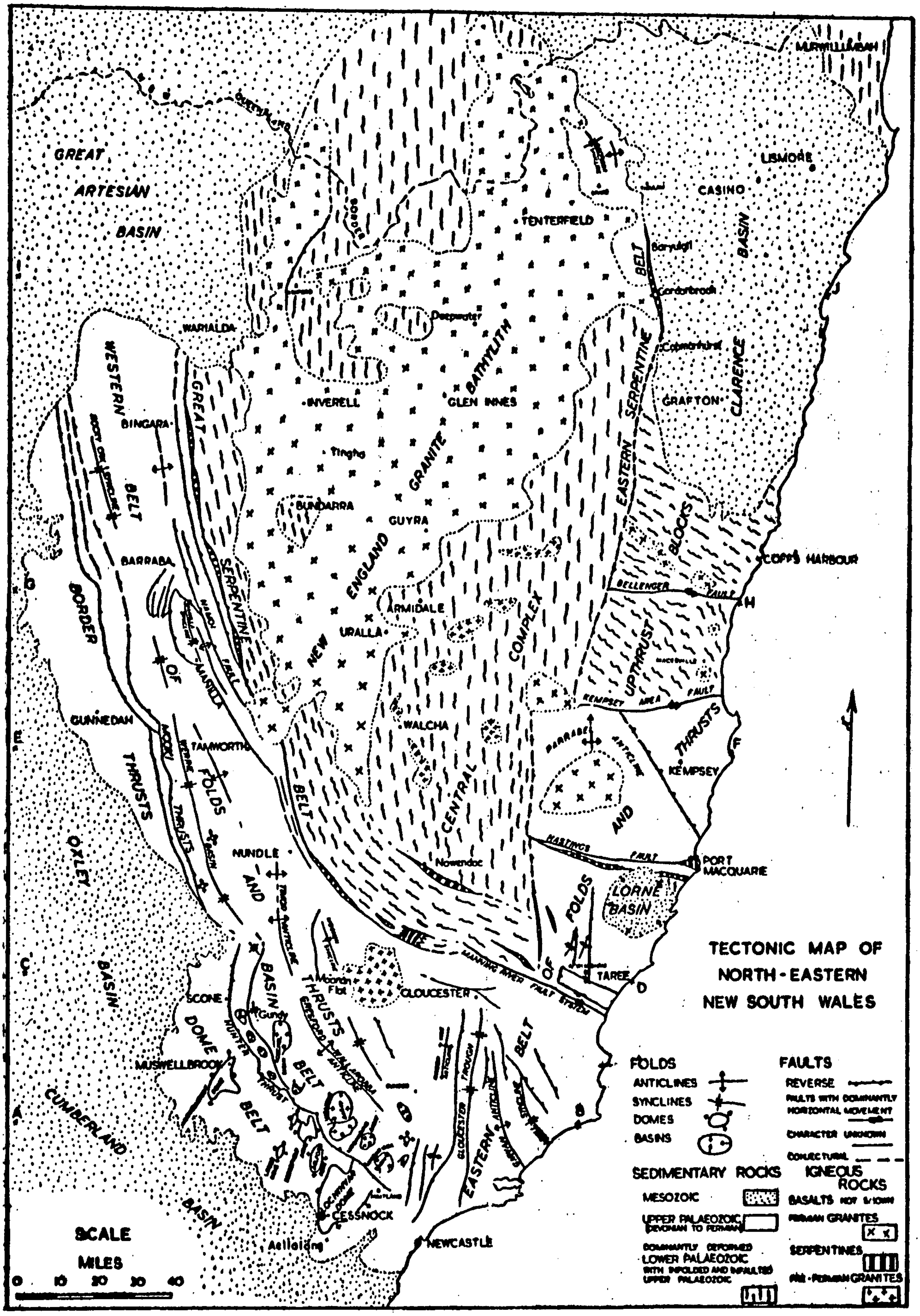

Fig. 2.—Tectonic Map of North-eastern New South Wales. (After Voisey, 1959)