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ANALCITE IN THE NEWCASTLE COAL MEASURE SEDIMENTS OF THE SYDNEY BASIN, AUSTRALIA

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ABSTRACT

The occurrence of analcite in the Newcastle Coal Measures of the Sydney Basin is described. The mineral, which comprises as much as 35 per cent of the sediment, is associated with abundant quartz and subordinate amounts of felspar and a regular mixed-layered clay mineral. Evidence indicates that the analcite formed from vitric tuffs in a highly saline basin prior to burial. As far as can be determined this is the first record of analcite occurring in sediments associated with commercially important coal seams.

INTRODUCTION

In recent years there has been a noticeable increase in the number of recorded occurrences of zeolite minerals in sedimentary rocks, a trend which undoubtedly has been brought about by the more widespread application of *x*-ray diffraction and other modern analytical procedures to the study of these rocks.

According to Coombs (1961) zeolites in sedimentary rocks may originate by either of the following processes.

Low-grade or burial metamorphism where the pressure-temperature conditions are intermediate between those of the green-schist facies and those of an essentially sedimentary environment. Turner and Verhoogen (1960) consider these zeolites form at depths ranging from 10,000 to 30,000 feet and at temperatures between 100 and 300 degrees centigrade.

Diagenesis where presumably burial has been less than 10,000 feet and the temperature below 100 degrees centigrade. From a study of the literature on sedimentary zeolites, Deffeyes (1959) concluded that analcite and clinoptilolite, the silica-rich end-member of the heulandite family, are by far the most common of the diagenetic zeolites, whereas Coombs (1961) believes the formation of these zeolites is especially favored by devitrification of parent volcanic glass, unusually saline conditions or abnormally slow sedimentation.

In the present paper a new occurrence of diagenetic analcite is described. The mineral is present to the maximum extent of 35 per cent of the rock and it occurs in silica-rich, tuffaceous sediments associated with productive seams of bituminous coal.

THE NEWCASTLE COAL MEASURES

In common with other Gondwana countries, Australia's principal coal-bearing strata are Permian in age. In the Sydney Basin of central-eastern New South Wales, the Permian is composed of two marine and three coal measure sedimentary groups of which the Newcastle is the uppermost in the northern sector (Fig. 1, Table 1).

The Newcastle Coal Measures attain a maximum thickness of 1,500

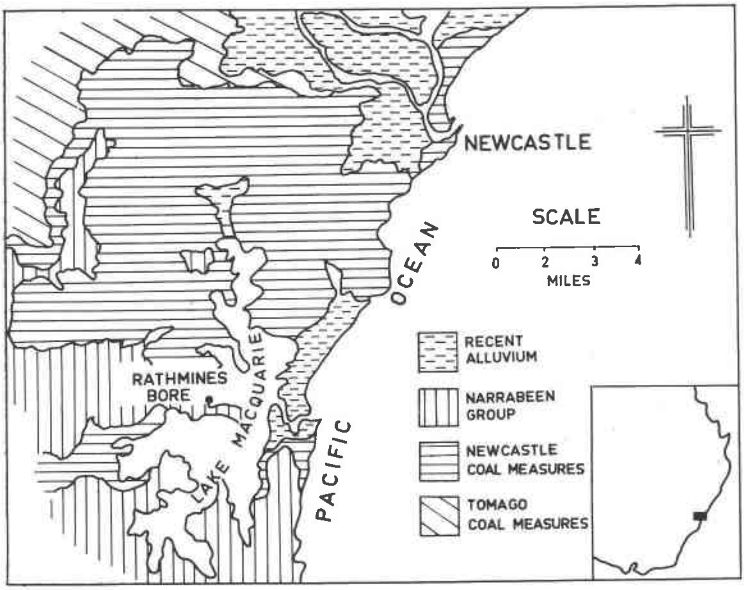

FIG. 1. Geological sketch map of the Newcastle coal measures.

TABLE 1. STRATIGRAPHIC SEQUENCE IN THE NORTHERN SECTOR OF THE SYDNEY BASIN

(maximum thicknesses in brackets after David, 1950)

TRIASSIC	
HAWKESBURY SANDSTONE (900′)	—Orthoquartzite with a few shale lenses
NARRABEEN GROUP (2,300′)	—Freshwater conglomerates, lithic sandstones and red and green claystones.
PERMIAN	
NEWCASTLE COAL MEASURES (1,500′)	—Freshwater conglomerates, lithic sandstones and tuffs with subordinate shales, claystones and approx. 15 coal seams.
TOMAGO COAL MEASURES (2,000′)	—Freshwater lithic sandstones, tuffs, claystones and shales with approximately 8 coal seams.
MAITLAND GROUP (6,400′)	—Marine shales, sandstones and conglomerates.
GRETA COAL MEASURES (1,000′)	—Freshwater conglomerates, sandstones and shales with several coal seams and splits.
DALWOOD GROUP (6,000′)	—Marine to brackish sandstones, shales, tuffs, conglomerates and lavas.
CARBONIFEROUS	

feet and outcrop over an area of approximately 200 square miles. They contain 15 coal seams although some of these are undoubtedly splits, and together with the Illawarra Coal Measures, their time-equivalent in the southern sector of the basin, they account for half of Australia's production of bituminous coal. The coal is of medium rank and is used mainly for steam-raising although in places it has been found suitable for metallurgical coke production

The intervening sediments are relatively coarse with conglomerates, lithic sandstones and tuffs predominating. However, shales and claystones occur throughout the succession and are particularly common in association with the seams. Some of the claystones are rich in montmorillonite and represent true bentonites (Grim 1960; Loughnan and See, 1959) but every gradation from these through to mixed-mineral assemblages of quartz, feldspar and mixed-layered clays is apparent. Elsewhere, the seams contain thin beds of indurated, kaolinite-rich claystone, which closely resemble the tonsteins of the Westphalian Coal Measures of Western Europe (Loughnan, 1962). The sediments show an overall decrease in grainsize towards the south-west, suggesting that the bulk of the detritus was derived from the north. This would agree with the known tectonic highs of Carboniferous lavas and clastic rocks which persisted in this area throughout much of Permian times (Raggatt, 1938).

The Newcastle Coal Measures are overlain by the Triassic Narrabeen Group which, in turn, is succeeded by the Hawkesbury Sandstone. Generally conformable boundaries separate each of these units. Apart from superficial Post-Tertiary deposits, it is very unlikely that sediments younger than Hawkesbury were ever present in the area. Therefore, since the Narrabeen Group has a maximum thickness of 2,300 feet and the Hawkesbury Sandstone 900 feet (David, 1950), the top of the Newcastle Coal Measures had a possible maximum depth of burial of the order of 3,200 feet.

Distribution and Composition of the Analcite-Bearing Sediments

The analcite was discovered during a routine investigation of samples obtained from a bore put down by The Broken Hill Pty. Co. Ltd., in the vicinity of Rathmines, 15 miles southwest of Newcastle (Fig. 1). The bore penetrated the full succession of the measures and sections of the core representing each change in lithology, were examined by microscopic, *x*-ray and chemical means. Of the 189 samples originally obtained, analcite was detected in 14 but only four contained the mineral in amounts greater than 20 per cent. The location of the analcite-rich samples in the stratigraphic column, are given in Fig. 2.

In hand specimen the analcite-bearing rocks are light-colored, dense and very tough, appearing intermediate between chert and sandstone. They occur as distinctive bands, generally less than 6 inches thick, in fine to medium-grained, greenish to grayish tuffs or volcanic sediments.

As viewed in thin section under the microscope, the rocks have a characteristic vitroclastic texture with isotropic shards and fragments ranging up to 1 mm in length. Angular grains of volcanic quartz (Krynine, 1946) up to 1.5 mm in diameter are common and feldspar (sanidine and/or

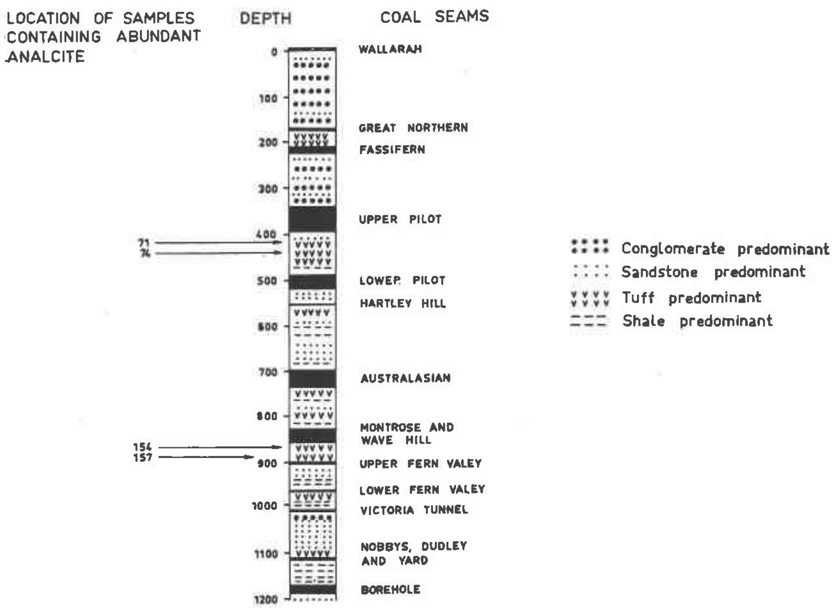

FIG. 2. Section through the Newcastle coal measures at Rathmines Bore No. 1 showing location of analcite rich samples.

albite) grains of comparable size occur sporadically throughout the rocks. There is no suggestion that the feldspar is secondary after analcite. Apart from a few isolated patches, clay minerals appear relatively rare.

The analcite occurs most commonly as a product of complete or partial alteration of the shards and vitric fragments. However, it also appears as pseudomorphs after felspar, as spherical masses similar to the quasi-oolites of Keller (1952) and as veinlets traversing the rock. Mostly it is isotropic but a few isolated grains of apparent analcite show very low birefringence. Differentiation of analcite from glass is often very difficult and an accurate assessment of the quantity of each constituent present by microscopic techniques is generally impossible. Consequently, for the quantitative determination of the mineralogy, resort was made to x-ray and chemical means.

The analcite-rich rocks were ground to pass a 325 mesh Tyler screen and then subjected to x-ray examination using a Philips 1010 diffractometer. The results revealed the presence of abundant quartz and analcite with subordinate amounts of feldspar and clay minerals. The quartz contents appeared considerably greater than were indicated by thin section examination, suggesting that much of the irresolvable devitrification

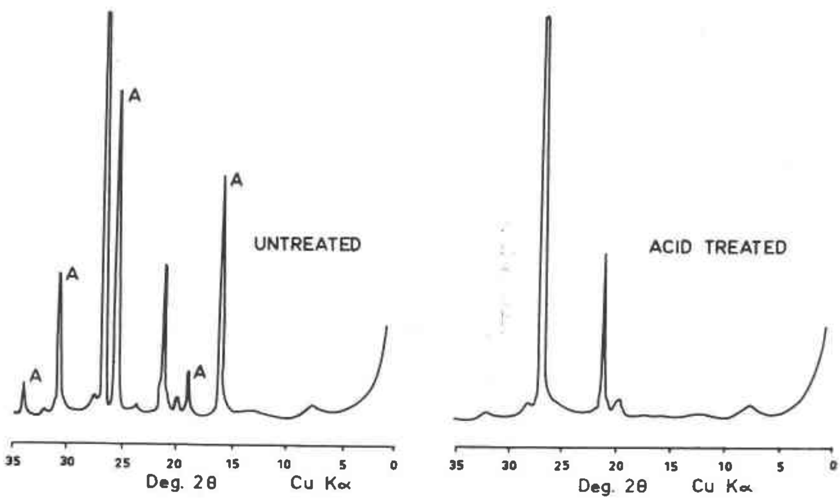

FIG. 3. X-ray data for analcitic sediment showing the effect of boiling in 2N HCl. A = Reflections due to analcite.

material is chalcedony. The samples were then boiled in 2N hydrochloric acid for one hour, filtered, washed and dried before being re-examined by x-ray diffraction. As shown in Fig. 3, all reflections attributable to analcite were destroyed by this treatment whereas the other minerals present appeared unaffected at least to the extent detectable by x-ray diffraction. Analyses were obtained of the soda contents of the filtrates by courtesy of G. T. See, and the quantities of analcite originally present were calculated from these values.

The x-ray reflections destroyed by boiling in 2N hydrochloric acid, together with the corresponding intensities based on peak heights, are compared with Coombs' (1955) x-ray data for analcite in Table 3. The agreement is quite good apart from minor differences in relative intensities.

Although clay minerals are not particularly abundant in these analcite-bearing sediments, nevertheless they show an interesting trend in composition. Samples containing analcite in amounts greater than 20 per cent are characterized by one clay mineral only *viz.* a regular mixed-layer of illite and montmorillonite. On the other hand, samples in which analcite is present but comprises less than 20 per cent of the rock, kaolinite occurs in addition to the regular mixed-layered mineral.

X-ray data for the oriented aggregates of the mixed-layered mineral

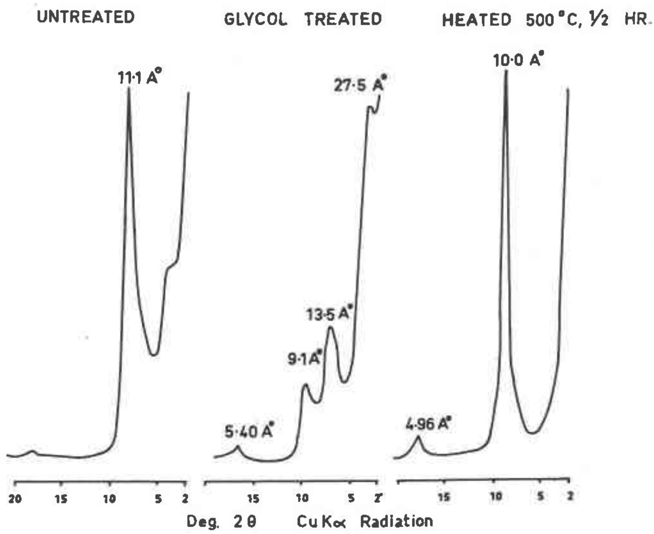

FIG. 4. *X*-ray data for oriented aggregates of clay mineral in sample 154.

are given in Fig. 4. The glycol-expanded sodium clay has a well-developed first order basal spacing at 27–28 Å with higher orders at 13.5 Å, 9.1 Å and 5.40 Å corresponding to the 002, 003 and 005 respectively. After heating the sample at 500° C. for one hour the basal spacing collapsed to approximately 10 Å with a somewhat weaker second order at 4.96 Å, yielding the illite structure. Replacement of the sodium with potassium or magnesium ions failed to produce any detectable difference to the *x*-ray pattern.

Chemical analyses of three of the analcite-rich sediments are given in Table 2 along with mineralogical data for the same samples. The mineralogical analyses have seen determined primarily from the chemical and *x*-ray data and no allowance has been made for amorphous materials although conceivably these may be present in significant proportions.

TABLE 2. CHEMICAL AND MINERALOGICAL ANALYSES FOR SOME OF THE ANALCITIC SEDIMENTS

(For locations of samples see Fig. 2)

Chemical Analyses[1]				Mineralogical Analyses			
	71	74	154		71	74	154
SiO_2	69.9	70.2	74.1	Quartz	50	55	55
Al_2O_3	16.1	14.2	14.2	Analcite	30	30	35
Fe_2O_3	1.89	1.47	1.85	Feldspar	10	4	4
TiO_2	0.28	0.20	0.18	Clay minerals	5	5	4
CaO	1.11	1.81	0.50				
MgO	0.87	0.65	0.25				
Na_2O	4.34	4.04	4.84				
K_2O	1.08	1.24	0.74				
H_2O+	3.70	5.51	3.62				
Total	99.3	99.3	100.3				

[1] Analyses by Aust. Coal Assn. (Research) Ltd. quoted on an oven-dry basis.

DISCUSSION

Microscopic examination of thin sections of the analcitic rocks leaves little doubt that the analcite is a secondary product, mainly after volcanic glass and is not detrital in origin. Furthermore, since the maximum accumulation of strata above the Newcastle Coal Measures at any period

TABLE 3. *X*-RAY REFLECTIONS DESTROYED BY TREATMENT OF SAMPLE 154 WITH HYDROCHLORIC ACID, COMPARED WITH COOMBS' (1955) DATA FOR ANALCITE

Analcite (Coombs, 1955)		Sample 154	
d	I[1]	d	I[2]
6.87 Å	1		
5.61	8	5.60 Å	74
4.86	4	4.82	16
3.67	2	3.65	6
3.43	10	3.43	100
2.925	5	2.92	44
2.801	2	2.79	6
2.693	5	2.69	16

[1] Visually estimated
[2] Relative peak height

since the Permian did not exceed 3,200 feet, the analcite cannot be attributed to burial metamorphism as defined by Turner and Verhoogen (1960). It would appear, therefore, that the analcite has formed by diagenetic processes, either prior to burial whilst the sediments were fully exposed to the lake waters or at a later period subsequent to burial by circulating ground waters. The limited extent of the analcite coupled with the paucity of soda in the associated sediments tends to favor the former alternative. The parent volcanic glass may have been detrital in the sense of having been transported some distance by streams but the relative purity of the sediment rather points to ash falls directly into the basin as the more likely source.

Since bentonite is the common alteration product of the vitric tuffs in the Newcastle Coal Measures, the sporadic development of analcite suggests unusual circumstances. Possibly a change in the chemical composition of the tuffs has played an important role influencing the formation of analcite instead of the usual bentonite, but more probably the controlling factor has been the environment for, undoubtedly, the analcite has resulted from a concentration of soda within the basin. It would appear that throughout most of the period of coal measure deposition, the basin had free drainage to the sea and much of the soda and potash released during the devitrification of the volcanic glass and breakdown of the feldspars, was lost from the basin. Under these conditions the lake waters were only moderately alkaline. However, if at times the drainage were blocked, evaporation would result in a concentration of the alkalies and in this environment analcite would develop as the stable crystalline phase from the reaction of soda with the volcanic glass. At the same time, the clay minerals probably adsorbed potassium ions forming a regular mixed-layered structure.

Acknowledgements

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