

Sedimentary analcime at Murrurundi, New South Wales, Australia

BERYL NASHAR

Department of Geology, The University of Newcastle, 2308, Australia

SUMMARY. Sedimentary analcime in a small basin in Cainozoic basalt at Murrurundi, New South Wales, has probably resulted from the reaction of Na-rich water on colloidal nontronite derived from volcanic ash. Based on cell dimension (13.713 Å) and $\Delta 2\theta(1.81)$ determined by Saha's (1959) method it is a Group C low-silica type of Coombs and Whetten (1967).

A SECTION of a small basin, approximately 5 m long and 1.5 m deep, in Cainozoic basalt was exposed as a result of mining operations in the New South Wales Department of Railways Basalt Quarry at Murrurundi, New South Wales. The basin was filled with a fawn to grey-green coloured, laminated sedimentary rock (fig. 1A and B). Amongst the rubble on the quarry floor were specimens of this laminated rock, basalt in contact with the rock, basalt containing veins of sedimentary material (fig. 1C), and green nontronite.

Microscopic examination of a thin section of a sample of laminated rock in contact with the basalt (fig. 1B) revealed tiny fragments of the sediment (approximately 2 mm in diameter) included in the basalt. The plagioclase laths in the basalt were arranged with a fluidal texture around irregularities on the surface of the sediment indicating a surface contact of the sediment with overlying basalt. Below the contact the sedimentary material had a very fine mesh-like structure suggesting that at the time of lithification it was possibly either a colloid or gel. Each minute area of the mesh (0.05 mm in diameter) was surrounded by a thin film of pale-green nontronite. Interspersed with the mesh-like material were laths of natrolite (0.05 to 0.1 mm long). There was no evidence of volcanic glass. Not all samples of the laminated rock revealed this mesh structure and the natrolite laths. Others revealed normal-looking fine-grained sediment in transmitted light but when viewed between crossed nicols the material was isotropic. Calcite occurred occasionally as a secondary mineral in spaces resulting from hydration (fig. 1A).

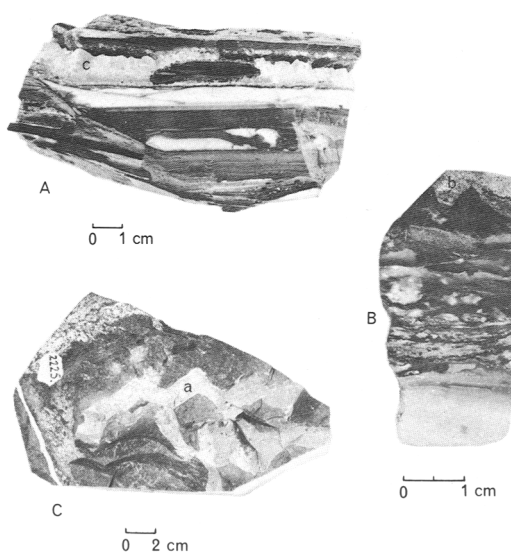


FIG. 1. A. Laminated sedimentary analcime with calcite (c) deposited in the space resulting from hydration. B. Laminated sedimentary analcime overlain by basalt (b). Note that irrespective of colour all of the material depicted in A and B except the calcite and basalt is analcime. C. Basalt with veins of sedimentary analcime (a).

X-ray analysis of the sedimentary material revealed it to be analcime. Likewise, the material in the veins in the basalt proved to be analcime with the development of natrolite at the contact with the basalt.

Sedimentary analcime has been described in the literature. The material under discussion compares favourably with the Wikieup, Arizona, analcime, described by Ross (1928) as follows: 'It has a gray-green colour, due to a thin film of nontronite clay between the grains of analcime that average 0.05 mm in diameter.' Wilkinson and Whetten (1964) have

summarized the known deposits. In discussing the origin of analcime-bearing sedimentary and pyroclastic rocks these authors proposed three types of origin: primary analcime as a product of saline lacustrine sedimentation; analcime of diagenetic origin where the analcime is the result of highly saline lacustrine waters reacting with volcanic ash and/or clay minerals; and analcime produced by burial metamorphism.

Later, on the basis of chemical composition (especially the silica content) of the analcime and the cell size and origin, Coombs and Whetten (1967) recognized three groups of sedimentary analcime: Group A silica-rich analcimes (approximate composition $\text{Na}_{13}\text{Al}_{13}\text{Si}_{35}\text{O}_{96}$ to $\text{Na}_{14}\text{Al}_{14}\text{Si}_{34}\text{O}_{96} \cdot n\text{H}_2\text{O}$) formed by the reaction of acid glass with playa lake waters; Group B analcimes with compositions close to $\text{Na}_{14}\text{Al}_{14}\text{Si}_{34}\text{O}_{96} \cdot n\text{H}_2\text{O}$ occurring in rocks for which a history of burial metamorphism is inferred; and Group C silica-poor analcimes (approximate composition $\text{Na}_{15}\text{Al}_{15}\text{Si}_{33}\text{O}_{96} \cdot n\text{H}_2\text{O}$ to $\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$) formed by either direct precipitation from highly alkaline water or by reaction of such water with clay minerals or other sedimentary materials.

From the above, it would appear that the composition of the analcimes is related to the mode and environment of origin. The analcime occurrence at Murrurundi is discussed below with these points in mind.

Optical, crystallographic, and chemical data of the Murrurundi analcime

The refractive index of the analcime is 1.490. The cell dimension (13.713 Å) and $\Delta 2\theta_{\text{Analcime}_{330} \text{Silica}_{331}}$ (1.81) determined by Saha's (1959) method are consistent with a silica-poor analcime that falls within Coombs and Whetten's (1967) Group C.

Using Coombs and Whetten's (1967) diagram depicting variation in cell size and composition of synthetic and naturally occurring analcime the composition of the Murrurundi analcime in terms of cations per unit cell ($O = 96$) is Si 32.5, Al 15.5, Na + K + 2Ca 15.5. On this basis the SiO_2 content is estimated to be about 56% by weight.

The fine grain size of the material precluded the clean separation of analcime from the nontronite and natrolite and hence the determination of the chemical composition of the analcime.

Two partial chemical analyses of the combined material (analcime, nontronite, and natrolite) gave the following results which indicated either a variation in chemical composition of the analcime, or varying proportions of nontronite and natrolite, or a combination of these.

	* SiO_2	† Al_2O_3	† MgO	† CaO
A	50.66%	20.97	0.16	0.12
B	58.38%	23.60	—	—
	† Na_2O	† K_2O	H_2O^+	H_2O^-
A	12.80	0.24	8.62	0.32
B	14.40	—	—	—

* Determined gravimetrically.

† Determined by atomic absorption spectrometry.

The refractive index and cell size were determined for sample A.

Origin of the analcime

The very fine-grained sedimentary material, probably finely divided basaltic ash, was deposited in a small body of water on top of the basalt. After deposition of the ash one of two processes could have occurred. Either the ash was converted to nontronite and thence to analcime or some of the ash could have gone direct to analcime and some to nontronite. In either case the alteration probably took place soon after deposition of the ash and before the outpouring of the overlying basalt. Cracks developed in this basalt and the sedimentary analcime oozed up into them.

The water in the lake was either condensed steam from the eruption or more likely meteoric water or a combination of both. The saline content could have been due only to solutes from the basalt and any fine fragmental basaltic material as a result of dissolution by the water.

Keller (1952) regarded the analcime of the Popo Agic Member of the Triassic Chugwater Formation of Western Wyoming as the alteration or reaction product of colloidal clays with strongly saline water whereby the sodium came from the water and the aluminium and silicon came from the clay. This origin is similar to that proposed by Ross (1928) for the Sikioup analcime and the one most likely for the Murrurundi analcime.

Because of the lack of relic ash structures in the analcime it is envisaged that the lake water enriched in sodium reacted with the nontronite, the alteration product of the basaltic ash, converting most of it to analcime. Noll (1936), Barrer and White (1952), and Barrer *et al.* (1959) have shown the feasibility of such a reaction by the synthesis of analcime from highly reactive aluminosilicate gels with excess NaOH at temperatures ranging from 150 to 450 °C. In the present case such temperatures could be provided by the cooling basaltic pile but the abundance of sodium is problematical.

Nashar and Basden (1965) determined the solubility of a similar basalt in cold distilled water at ambient temperature and pressure and found that

after 24 hours the resultant solution contained 6.50 ppm Na₂O (4.81 ppm Na⁺) and after 6 months 7.20 ppm Na₂O (5.33 ppm Na⁺). Keller and Reesman (1963) recorded the mean value of 14 ppm Na⁺ from the dissolution of gabbro-diabase-basalt flow rocks. The highest value was 28.1 ppm from basalt from the Sunset Crater, Arizona. All of these figures are far lower than those indicated by Boles (1971) as being necessary for the synthesis of analcime from natural heulandite and clinoptilolite, viz. 4600 ppm Na⁺ (0.1M Na₂CO₃) or 2760 ppm Na⁺ (0.01M Na₂CO₃ + 0.1M NaCl) and the concentrations of Na⁺ in saline lakes (2360–132 000 ppm) given by Hay (1966) and Jones *et al.* (1967).

The only feasible suggestion is that concentration in the small body of water may have been achieved as the result of repeated fill and evaporation.

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