jadeite. Of course, there may also be a maximum shock pressure associated with the formation of jadeite from sodic feldspar, above which other high-pressure phases are produced (*13*). Jadeite has not been observed as a shock product in laboratory experiments, however, and there are great uncertainties involved in extending the results of these experiments to naturally shocked rocks. In natural impact the duration of the pressure pulse may be much greater than in laboratory dynamic experiments; since the formation of jadeite is a chemical breakdown apparently requiring diffusion over distances on the order of 0.1 to 0.5 μm (Fig. 2), the duration of the peak pressure should be an important factor in determining whether the reaction will occur and what pressure is required.

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1. The term thetomorphic was introduced by E. C. T. Chao [*Res. Geochem.* **2**, 212 (1967)] to describe glasses produced from minerals by shock transformation in the solid state.
2. Origin of the Ries Crater by meteor impact has been established by the occurrence of the high-pressure polymorphs of quartz—coesite and stishovite [E. M. Shoemaker and E. C. T. Chao, *J. Geophys. Res.* **66**, 3371 (1961); E. C. T. Chao and J. Littler, *Geol. Soc. Amer. Abstr.* **1962**, 127 (1963)].
3. Refractive indices were determined by E. C. T. Chao and Miss J. Boreman with an interference microscope.
4. Extrapolation of the results of static high-pressure laboratory experiments indicates that jadeite can coexist with free silica at room temperatures only at pressures above 6 kb [F. Birch and P. LeCompte, *Amer. J. Sci.* **258**, 209 (1960)].
5. The most common lines attributed tentatively to unidentified alteration products have *d*-spacings of 2.71, 2.16, 2.02, 4.00, 2.54, and 2.34 Å. Line intensities are strongest in grains that contain abundant calcite and montmorillonite and little or no jadeite.
6. H. S. Yoder, *Amer. J. Sci.* **248**, 225 (1960).
7. Cell parameters were calculated and refined by computer by use of the least-squares method [D. E. Appleman and H. T. Evans, Jr., *Geol. Soc. Amer. Spec. Pap.* **115**, 8 (1968)].
8. I calculated the mean refractive index of the assemblage by assuming the following values for density (in grams per cubic centimeter) and refractive index:

| Component | ρ | R.I. |
|---|---|---|
| Anorthite | 2.76 | 1.583 |
| Albite | 2.62 | 1.532 |
| Orthoclase | 2.56 | 1.522 |
| Quartz | 2.65 | 1.548 |
| Silica glass | 2.20 | 1.460 |
| Jadeite (pure) | 3.30 | 1.660 |
| Jadeite (with Ca-Al substitution for Na-Si) | 3.33 | 1.670 |

In estimating refractive indices of assemblages containing impure jadeite, it is assumed that only 75 percent of the original oligoclase breaks down to jadeite + $SiO_2$ (necessitated by the observation that jadeite forms only about half the volume of the particles). Volume relations for the four assemblages are:

| Component | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Jadeite | 0.50 | 0.48 | 0.49 | 0.47 |
| Anorthite | .25 | .24 | .06 | .06 |
| Albite | | | .20 | .19 |
| Orthoclase | .07 | .07 | .07 | .07 |
| Quartz | .18 | | .18 | |
| Silica glass | | .21 | | .21 |

9. The thetomorphic oligoclase glass in this sample has a refractive index about 0.007 higher than that of "normal" glass, but this difference is, in part, due to the presence of water (P. M. Bell and E. C. T. Chao, *Carnegie Inst. Wash. Annu. Rep. 1969*, in press).
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12. F. Hörz, in *Shock Metamorphism of Natural Materials*, B. M. French and N. M. Short, Eds. (Mono, Baltimore, 1968), p. 243.
13. Among the possibilities are: (i) breakdown into corundum plus amorphous or crystalline silica and sodium compounds [D. H. Lindsley, *Carnegie Inst. Wash. Annu. Rep.* **65**, 204 (1967)]; or (ii) transition to a dense polymorph of feldspar in which Si and Al are in octahedral coordination [A. E. Ringwood, A. F. Reid, A. D. Wadsley, *Earth Planet. Sci. Lett.* **3**, 38 (1967)].
14. I am grateful to E. C. T. Chao and Miss J. Boreman of the U.S. Geological Survey for the determinations of refractive indices, to J. A. Minkin of the Geological Survey and A. J. Tousimis of Biodynamics, Inc., for the electron micrographs, and to C. Hadidiocos and P. M. Bell of the Carnegie Institution of Washington for the microprobe analysis of the maskelynite and the sample of synthetic jadeite. Research done on behalf of NASA by the U.S. Geological Survey. Publication authorized by the director, U.S. Geological Survey.

23 July 1969

## Algal Stromatolites: Deepwater Forms in the Devonian of Western Australia

Abstract. *A diverse assemblage of algal stromatolites occurs in Devonian reef complexes of the Canning Basin, Western Australia. Some forms grew on fore-reef depositional slopes down to at least 45 meters below sea level and are believed to be products of deepwater nonskeletal algae. It is concluded that algal stromatolites in the stratigraphic record are not to be regarded as diagnostic evidence for deposition in very shallow water.*

Algal stromatolites have been studied in considerable detail by sedimentologists in recent years. Modern marine forms are known mainly from supratidal and intertidal environments, although a few shallow subtidal occurrences have been recorded (*1*). They have formed through the trapping and binding of calcareous sedimentary particles by algal mats, and are best known from Hamelin Pool, a hypersaline barred embayment forming part of Shark Bay in Western Australia (*2*). Ancient stromatolites are regarded by most authorities as close analogs of these modern forms. However, there has been some debate over the validity of this analogy, especially as to whether most ancient stromatolites formed within or below the tidal range, whether biological or environmental factors were dominant in determining their shapes, and whether binding and trapping of sediment by algae were exclusively responsible for their growth (*3*).

We now report the discovery of a diverse assemblage of algal stromatolites that grew to depths of at least 45 m below sea level on fore-reef slopes of Devonian reef complexes in Western Australia. They are believed to be products of deepwater nonskeletal algae (possibly red-pigmented cyanophytes) which trapped and bound sedimentary particles and also precipitated calcium carbonate. This discovery is of considerable significance in the environmental interpretation of ancient algal stromatolites, as it shows that they were not confined to supratidal, intertidal, and very shallow subtidal environments as has generally been supposed.

Middle and Upper Devonian reef complexes are excellently exposed along the northern margin of the Canning Basin in Western Australia (*4*). Reef, back-reef, fore-reef, and inter-reef facies are recognized (Fig. 1). Calcareous algae and stromatoporoids are the main reef frame-builders, and these groups are also important constituents of the back-reef facies. The algal flora is among the most diverse and abundant known from the Devonian (*5*). The reefs grew up to 100 m or more above the sea floor of the surrounding inter-reef basins.

Algal stromatolites occur in the reef, back-reef, and fore-reef facies (Fig. 1) but are most abundant and diverse in the fore-reef, especially in the Frasnian to Famennian Virgin Hills Formation of the Bugle Gap area. The fore-reef stromatolites grew on depositional slopes that were usually inclined at from 10° to 35°, but were occasionally as high as 55°. Stromatolitic algae played an important part in binding the fore-reef deposits, and they were responsible for maintaining the abnormally high depositional dips present in some areas. The amount of depositional dip can be determined by using

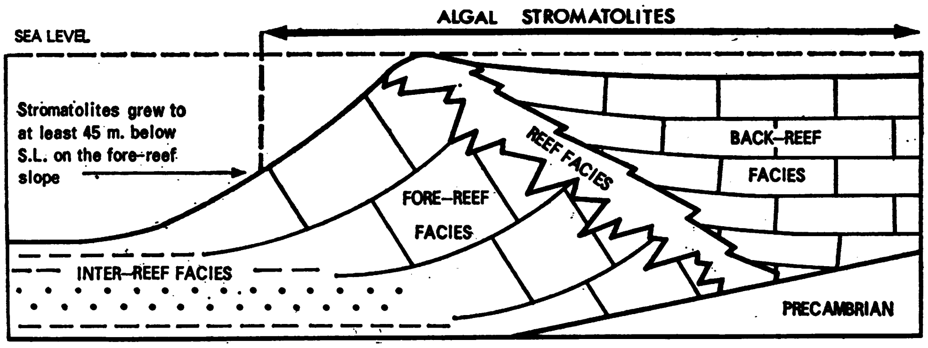



Fig. 1. Section illustrating development of a Canning Basin reef complex and the distribution of algal stromatolites.

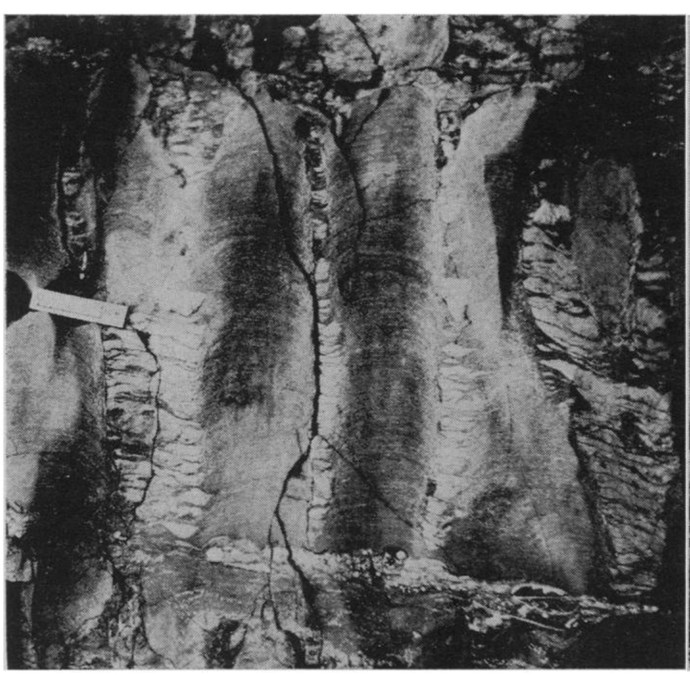
geopetal structures that indicate the horizontal at the time of deposition, especially fillings of brachiopods, gastropods, ammonoids, and nautiloids. The fillings commonly consist of laminated lime mud at the base and sparry calcite above, the contact between them being a conspicuous planar surface which marks the original horizontal. Algae growing on the fore-reef slopes tended to grow vertically (toward the light) and they can therefore be used to confirm the amount of depositional dip in some areas (Figs. 2 and 3).

Many different stromatolite growth forms occur in the fore-reef deposits. They grade from one to another and are difficult to classify satisfactorily. The main forms can be described as columnar, longitudinal, undulatory, contorted-bulbous, mound-shaped, planar, reticulate, and nodular stromatolites. Most are finely laminated and dense. The stromatolites were formed by nonskeletal algae, both by precipitation of calcium carbonate and by trapping and binding of terrigenous and calcareous clastic particles. Both types of growth are commonly represented in a single stromatolite, and a continuous gradation occurs between them. Well-preserved algal threads are abundant in some types, but many show no trace of threads. Some of the stromatolites are encrusted with holdfasts of small crinoids and corals, and apparently grew as rather hard and rigid bodies. Other conspicuous elements of the associated open-marine fauna are ammonoids, nautiloids, and conodonts.

Columnar stromatolites are the most striking forms in the fore-reef facies. They reach a maximum height of about 1 m, and typical examples are about 25 cm high and 6 cm wide. During growth they rarely had more than 6 cm of relief and commonly stood almost vertically on the fore-reef slopes (Fig. 2). Few show any recognizable algal threads. The longitudinal stromatolites are generally oriented with the long axis of each parallel to the dip of the fore-reef slopes on which they grew.

Algal stromatolites that occur in the shallow-water reef and back-reef facies are generally irregular columnar forms. They are not as regularly laminated as those in the fore-reef facies, and frequently show bird's-eye textures. Some probably grew within the tidal range. Oncolites (algal nodules) are common in parts of the back-reef facies, and they also occur occasionally in reef facies. Some oncolites show well-preserved algal threads, but these are absent in others. At McWhae Ridge, in Bugle Gap, oncolites were swept from the reef down the fore-reef slope, coming to rest on depositional slopes of 35°. Algal growth continued in the form of finely laminated conical caps that grew vertically on some of the oncolites (Fig. 3).

The original water depth at any point on a fore-reef slope can be deduced in areas where the fore-reef bedding can be traced up to meet reef facies of the same age. Where the dip



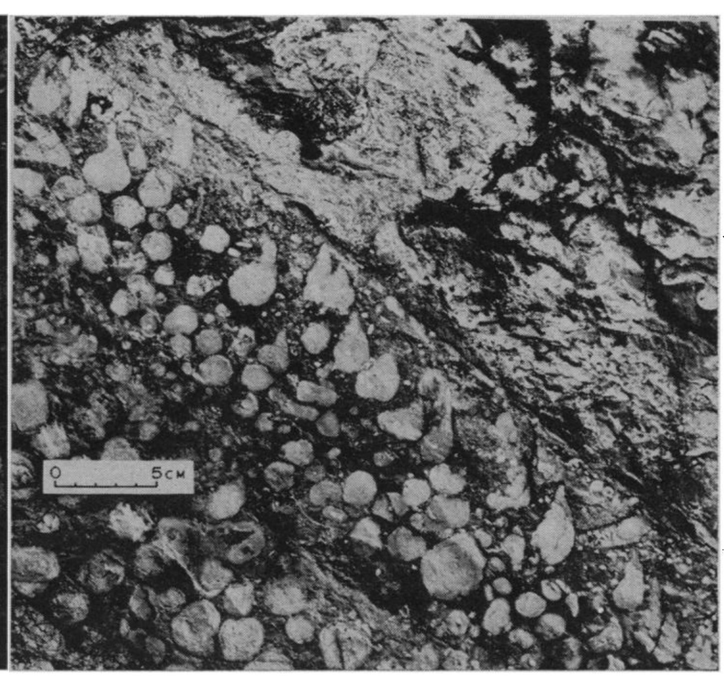



Fig. 2 (left). Columnar stromatolites in fore-reef facies (Virgin Hills Formation) at the southern end of Bugle Gap. The stromatolites grew vertically on a fore-reef depositional slope of 12°. Fig. 3 (right). Oncolites and capped oncolites in fore-reef facies (Sadler Limestone) at McWhae Ridge, Bugle Gap. The oncolites were swept from the adjacent reef, coming to rest in deep water on a depositional slope of 35°; conical algal caps then grew vertically on some of them.

of the fore-reef deposits is entirely depositional, the original water depth is equal to the present difference in elevation between the point and the equivalent reef crest, provided that the reef crest grew at sea level. In practice, however, only the approximate water depth can be determined in this way, because of outcrop limitations and the impracticability of demonstrating exact correlation between a particular bedding plane and its equivalent reef crest. Moreover, the reef crest may have stood significantly below sea level in some areas.

The best locality to deduce approximate water depths for algal stromatolites in fore-reef facies is in the Virgin Hills Formation adjoining McWhae Ridge, a ridge of reef 1.75 km east-southeast of Cave Spring in Bugle Gap. Columnar and longitudinal stromatolites in their growth positions are well developed at this locality, and they grew on depositional slopes as high as 40° to 45°. Detailed study of geopetal structures indicates that post-depositional steepening of the fore-reef dip is slight, amounting to no more than 6°. The stromatolites cut out passing down the fore-reef slopes 45 m to 50 m below the crest of the reef ridge. At the present level of erosion, the top of the reef on McWhae Ridge is believed to be equivalent to fore-reef strata several meters stratigraphically lower than the stromatolite-bearing beds. It is accordingly concluded that in this area the deepest of the stromatolites must have grown in water at least 45 m deep.

Our study has thus shown that abundant and varied algal stromatolites grew to considerable depths below sea level in the Canning Basin reef complexes, and that they were formed by both sediment-binding and carbonate-precipitating algae. Accordingly, the presence of algal stromatolites in ancient sedimentary rocks cannot be accepted as diagnostic evidence that those sediments were deposited within the tidal range or in very shallow subtidal environments.

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6. This study is part of a biostratigraphic research project on the Devonian of the Canning Basin being carried out by the Geological Survey of Western Australia and the Australian Bureau of Mineral Resources. We thank E. C. Druce, J. S. Jell, and M. S. Petersen for assistance in the field, and B. E. Balme, D. C. Lowry, and J. L. Wray for reading the manuscript.

22 April 1969

## Autosomal Trisomy in a Chimpanzee: Resemblance to Down's Syndrome

Abstract. *An infant chimpanzee* (Pan troglodytes) *with clinical, behavioral, and cytogenetic features similar to those in Down's syndrome is described. The infant shows retarded growth rate, congenital abnormalities, retarded neurologic and postural development, epicanthus, hyperflexibility of the joints, muscle hypotonia, and trisomy of a small acrocentric chromosome.*

The most frequent form of Down's syndrome (Mongolism) (*1*), trisomy of a G-group chromosome (*2*), is reported to occur in the human population with a frequency of approximately 1 in 600 births (*3*). Other types, such as translocation or mosaicism, are much less frequent. Comparable conditions have not previously been reported in any species of nonhuman primate.

The subject of this report is a female chimpanzee (*Pan troglodytes*), born 6 July 1968. This infant (Jama) was delivered after an apparently normal and uncomplicated pregnancy. The mother (Wenka) had one previous pregnancy which resulted in a premature stillbirth

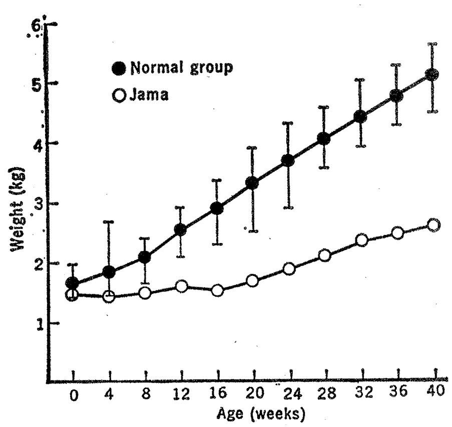


Fig. 1. Comparison of weights from birth to 40 weeks for Jama and a group of chimpanzees raised under similar nursery conditions. Both males and females are included in the group average and range (vertical line). The number of subjects included in the group curve varies between five and seven over the 40-week period, because two of the animals are younger than Jama.

28 months before Jama was born. Wenka is now 15 years old and the father (Frans) is 22. Since the reproductive period for laboratory chimpanzees is usually between 10 and 30 years of age, Wenka is classified as a relatively young breeder. No other relevant medical history has been recorded for either the mother or father.

Jama was of low-normal birth weight and has exhibited a slow rate of growth, compared to other laboratory-reared chimpanzees (Fig. 1). In contrast to other chimpanzees in our colony, she has bilateral, partial syndactyly of the toes with clinodactyly, prominent epicanthus, hyperflexibility of the joints, and a short neck with excess skin folds. An undetermined type of cardiac defect was radiographically observed shortly after birth (*4*). Further diagnostic radiography has been postponed because of possible risk to her survival. She continues to show poor clinical progress, as judged by retarded growth and delayed neurologic development. The Moro reflex is absent, there are marked hypotonia, abnormal traction and suspension responses, and general inactivity. At 40 weeks of age, Jama is still unable to sit up or move about in her cage. She has had recurrent bouts of enteric and upper respiratory disorders; however, such infections are not uncommon in laboratory-reared chimpanzees.

Systematic behavioral observations support the conclusion that her postural development is markedly retarded, especially when compared with other Yerkes nursery animals and the critical-age norms reported for chimpanzees