that at the second melting a minimum volume in the range of 20 to 40 percent of the portion of the moon below 200 to 400 km became hot enough to melt the mare basalt. This is so large a fraction of the moon that it is highly probable that everything below the deep outer layers became extremely hot very early in the moon's history and again when the maria were formed. Since the moon was hot when the basalts rose, it is still hot. No calculations I have seen suggest that a hot moon could cool significantly at depths of a few hundred kilometers within geologic time. Even convection could only help to cool the inner moon to the point where it could no longer convect.

The thesis that the lavas of the maria came from surface heating no longer should be considered valid. The deep moon must be hot, although not necessarily molten. The surface is cool, and we may infer a transition zone in the outer few hundred kilometers.

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24 August 1970

Soft Parts of Cephalopods and Trilobites: Some Surprising Results of X-ray Examinations of Devonian Slates

Abstract. *X-ray studies of slates from Bundenbach and Wissenbach (Lower and Middle Devonian, West Germany) revealed a surprising amount of pyritized soft parts of cephalopods and trilobites. The tentacles of cephalopods, the appendages, the intestinal tract, and the structure of the interior of facet eyes of trilobites* (Phacops *species and* Asteropyge *species) were found in a well-preserved state.*

The discovery of soft parts of Paleozoic fossils is a very rare event (*1*). During an extended x-ray investigation of Devonian fossils from the famous localities of Bundenbach and Wissenbach (Lower and Middle Devonian, West Germany) many unprepared slates were found in which soft parts and extremely fine structures of the embedded fossils are preserved. These structures, consisting of a very fine-grained pyrite, are so delicate that they are normally destroyed by the usual mechanical preparation of the specimens. Examination with soft x-rays (25 to 40 kv) showed that this pyritized material gives good contrast because of the high absorption coefficient of pyrite. From these observations it was concluded that the preservation as pyrite depends largely upon the locality. It is not known what initiated the formation of pyrite in those parts of the buried animal which contained large amounts of albumin and other constituents with high sulfur content. The products of decomposition were adsorbed on the enclosing fine sediment and held in this

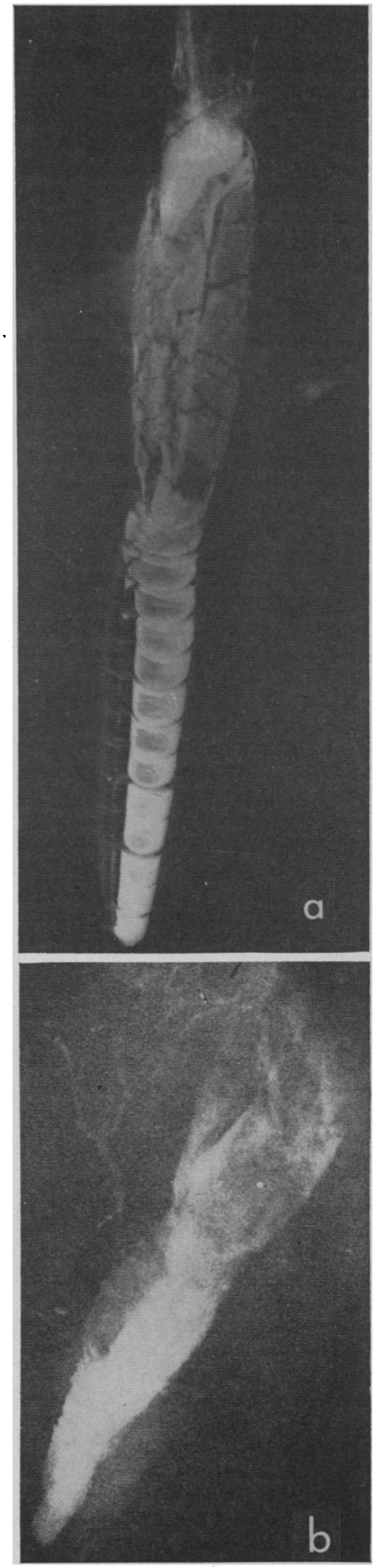

Fig. 1. (a) *Lobobactrites* sp., a cephalopod with tentacles. Right of the center, a very young cephalopod. (b) Very young embryonic stage of a cephalopod (*Orthoceras*).

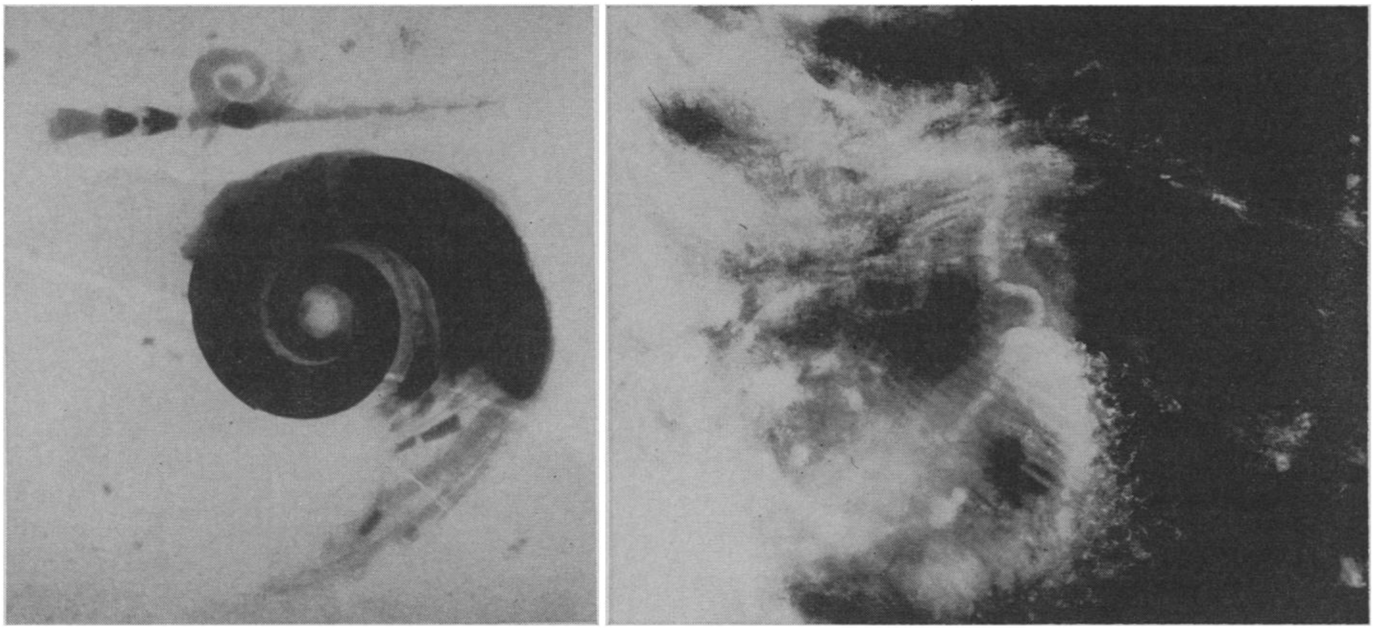

Fig. 2 (left). *Goniatites* with tentacles (× 5). Fig. 3 (right). Facet eye of the *Phacops* sp. (Broili, 1930) (see cover). At right the single facets are clearly visible. Bundles of fibers go to the upper left (× 15).

position until iron ions, transported along by water or diffusion, caused the formation of FeS_2 (*2, 3*).

Most of the specimens, unprepared and prepared, are preserved in the West German collections of the Senckenberg Museum in Frankfurt am Main as well as the Paleontological Institute of the University of Bonn and the Bavarian State Collection in Munich. Some of the trilobites were described after mechanical preparation several decades ago by Broili (*4*) and by Lehmann (*5*), but the reexamination revealed many unknown and unobserved details.

The first x-ray observations were made on Middle Devonian shales from Wissenbach (*6*). Many of the goniatites and orthoceratites of this locality show details, not previously observed, that are somewhat difficult to explain. The tentacles of a *Lobobactrites* sp. and of goniatites are shown in Fig. 1, a and b, and in Fig. 2. The young animals are very early embryonic stages of similar cephalopods.

The fossils of the Lower Devonian from the famous Hunsrück localities of Bundenbach and Gemünden also show very good preservation of details

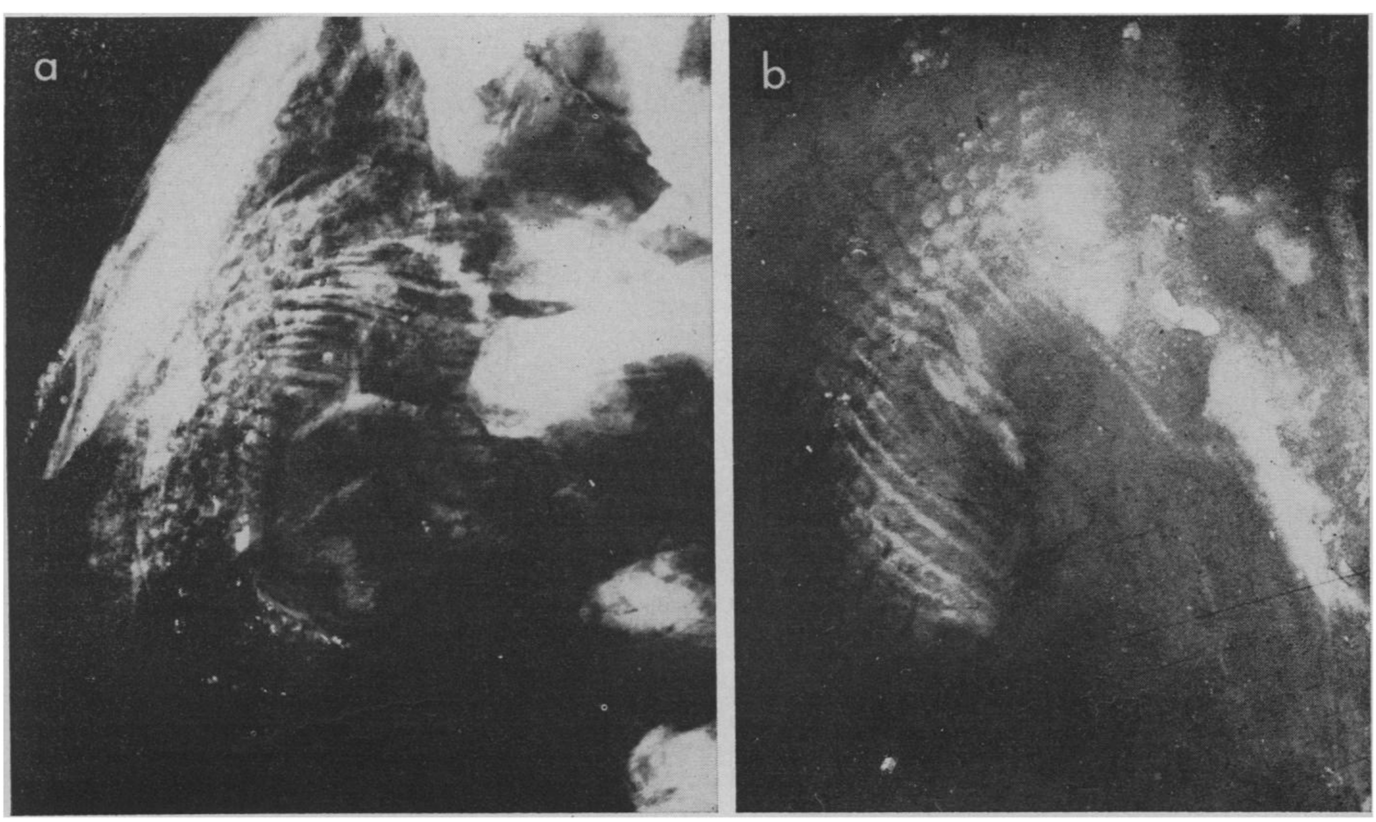

Fig. 4 (a and b). Eyes of *Phacops* sp. with facet and fiber structures (a, × 10; b, × 15).

Fig. 5. Cephalon of an *Asteropyge* sp. (Lehmann, 1934) (× 4.5).

of soft parts, especially in the trilobites examined so far.

The famous *Phacops* sp. (cover photograph) described in 1930 by Broili (*4*; *7*, figure 57E, p. O 81) shows details that cannot be made visible by mechanical preparation. Now observable on the x-ray photographs are the intestinal tract as well as the appendages with the gill filaments and other details, the most surprising of them being light guides leading from the facets of the eyes of the *Phacops* nearly to the center of the head (Fig. 3). There seems to be a significant difference between the facet eye structure of the horseshoe crab (*Limulus polyphemus*) and the eye of *Phacops* [earlier and recent work on the lens structure of trilobites did not reveal such details (*8–10*)]. The eyes of other *Phacops* species show similar structures (Fig. 4). In no case were interconnections found between the single fibers as described and explained in their function by Miller *et al.* (*11*) and by Ratliff *et al.* (*12*). From these observations it must be concluded that the filamentary structures are probably real light guides and not nerve bundles (as in the *Limulus* eye) guiding the light from the cornea over a rather long distance to the receptors in the vicinity of the brain. Contrary to the structure of the *Phacops* eyes, that of another trilobite, *Asteropyge* sp., described by Lehmann (*5*; *7*, figure 57A, p. O 81), shows more similarities to normal facet eyes of the insects (Fig. 5). Details of the eyes of this specimen were first revealed on an x-ray photograph by Lehmann (*5*), but he hesitated to explain what he saw as it seemed incredible to him that "the nerve bundles were going at an angle of about 45° backwards to a place where the ganglion of the lower throat is located" (*13*, figures 47 and 1). New radiographs of the specimen confirmed these earlier observations.

My experience with prepared and unprepared fossils of Devonian slates suggests that no mechanical preparation should be done prior to a thorough x-ray examination, in order to avoid the destruction of important fine details. In the course of the survey made in the last 2 years, several completely unknown Devonian fossils have been discovered.

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27 April 1970

Hindered Diffusion in Microporous Membranes with Known Pore Geometry

Abstract. *The hindrance effect on the aqueous diffusion rate of solutes within membrane pores of molecular size has been accurately determined. Mica membranes, 3 to 5 micrometers thick, were prepared with uniform, straight pores from 90 to 600 angstroms in diameter. With these membranes a direct estimation was possible of the interaction between pore size and molecular diffusion rates. There were no uncertainties due to wide pore size distributions or nonuniform tortuous channels as in previously used model microporous materials such as dialysis tubing or gels. Aqueous diffusion rates through these mica membranes were measured for a series of compounds with molecular diameters from 5.2 to 43 angstroms and were corrected for "liquid film resistances" adjacent to the membrane-solution interface to obtain estimates of molecular diffusivities within the micropores of the membrane. Definite evidence is presented showing that, even when molecular size is a small fraction of pore size, diffusion rates decrease markedly. The apparent reduction in solute diffusivity in the microporous membrane can be quantitatively estimated by means of the Renkin equation for hindered diffusion.*

The extent of the influence of pore size on the liquid diffusion rate of solutes in microporous materials is important in biological membranes (*1*), separations by dialysis (*2*), and gel permeation chromatography (*3*). Although several investigators have attempted to quantitate the reduction in solute diffusivities within pores (*4*, *5*), the interpretation of the results obtained has been somewhat inconclusive in view of the fact that the porous ma-