Tungsten Diboride: Preparation and Structure

Abstract. *A new tungsten boride has been prepared and has been assigned the formula WB_2. The assignment is based on comparison of the x-ray diffraction data of this boride with those of diborides of the AlB_2 type structure. Values of $a_0 = 3.02$ and $c_0 = 3.05$ were calculated for a hexagonal unit cell.*

Although many attempts have been made to prepare a tungsten boride of the AlB_2 type structure, no WB_2 phase has been reported, according to a review of refractory binary borides by Post (*1*). We have prepared WB_2 (AlB_2 type structure) by heating an amorphous boron wire in an atmosphere of WCl_6 and argon. In a typical preparation, a boron substrate 100 μ in diameter was heated resistively, in an argon stream containing about 0.03 percent WCl_6 by volume, to 800°C and kept there for 30 minutes. The total pressure in the reaction chamber was 10 torr. As shown in Fig. 1, the material formed as a layer on the surface of the boron substrate. The dark objects that appear beneath the boride layer in the photomicrograph are voids in the boron, resulting from cleavage of the filament. Emission spectrographic analysis of the sample showed that only tungsten and boron were present in concentrations above 50 parts per million.

Debye-Scherrer x-ray diffraction photographs of the fiber were taken with a 114.7-mm-diameter camera and Ni-filtered Cu radiation. The diffuse halos from the amorphous boron substrate were observed on the diffraction film but did not interfere with the x-ray analysis. Observed and calculated values of *d*-spacings, relative intensities, and Miller indices are given in Table 1. All lines of the x-ray photographs were indexed on the basis of a hexagonal unit cell with $a_0 = 3.02 \pm 0.002$ and $c_0 = 3.05 \pm 0.002$. There is one molecule per unit cell, and the calculated density is 14.15 g/cm^3. Corrections were not made for film shrinkage.

Table 1. X-ray data for WB_2.

Lattice plane spacing (Å)		Relative intensity*	Miller indices
Observed	Calculated	(I)	(hk · l)
3.05	3.05	M	001
2.62	2.62	VS	100
1.99	1.99	VS	101
1.526	1.525	W	002
1.510	1.515	M+	110
1.354	1.354	M	111
1.320	1.318	M-	102
1.308	1.308	M-	200
1.202	1.202	M-	201
1.073	1.073	W+	112
1.016	1.017	VVW	003
0.9885	0.9889	M-	210
.9474	.9476	VVW	103
.9400	.9407	M	211
.8713	.8721	VVW	300
.8432	.8434	VVW	113
.8384	.8385	VW	301
.8296	.8297	VW	212
.8029	.8027	VW	203

* Intensities: M, medium; VS, very strong; W, weak.

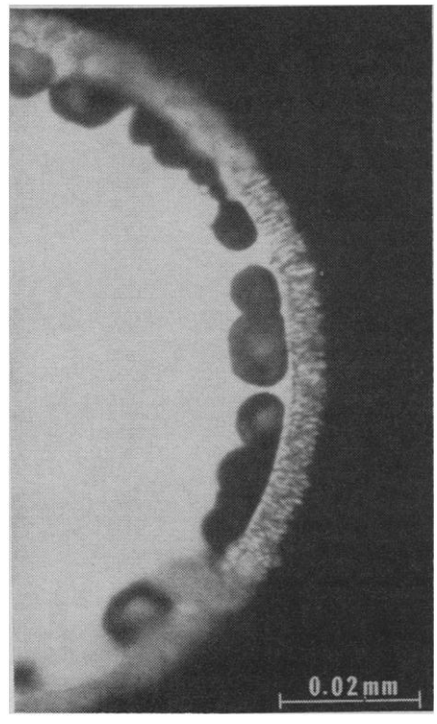

Fig. 1. Cleaved boron fiber showing layer of tungsten diboride.

Comparison of the x-ray data with those of other diborides (particularly MoB_2 and MnB_2, which have similar c/a ratios) suggests that this new boride is isomorphous with diborides of the AlB_2 type structure. Hence it is assumed that the material belongs to the space group C6/mmm and has the stoichiometric formula WB_2.

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References and Notes

1. B. Post, in *Boron, Metallo-Boron Compounds and Boranes*, R. M. Adams, Ed. (Interscience, New York, 1964), p. 342.
2. We thank L. R. Taylor, Jr., for assistance and Gordon H. Miller for discussion. Work supported by NASA contract NAS 3-4196.

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Wormlike Fossil from the Pennsylvanian of Illinois

Abstract. Tullimonstrum gregarium *was a common, possibly marine, invertebrate in certain shallow, offshore waters of northern Illinois during the Middle Pennsylvanian. It had a flexible proboscis armed with teeth; a mobile tail; and a curious transverse bar behind the head, bearing a pair of round, external organs.*

In the past few years, fossil collecting from the Middle Pennsylvanian Francis Creek shale in the old strip-mine dumps of Will and Grundy counties in Illinois (*1*) has become less productive as the spoil heaps have become overgrown and as large areas have been set aside as private recreation land. A large and almost wholly undescribed fauna in the same beds, in the old McAlester pit 2 miles south of Braidwood and in the adjacent (and still active) Pit 11 of the Peabody Coal Company, astride the Will-Kankakee county line, was called to my attention about 1958 by Francis J. Tully, of Lockport, Illinois. One of the most abundant members of this fauna is the large, soft-bodied invertebrate described below. Since then, as the fervent amateur collectors of the Chicago area learned of the new locality, this fossil has come to be well represented in many private collections and is universally called the "Tully monster." In basing its proposed Linnean name on this designation, I honor Tully for his discovery, acknowledge his having disclosed it, and formalize a widely used common name.

Both the Tully monster and the fauna of which it is such an outstanding ornament are being studied (*2*), but it seems proper and necessary to present this brief description and preliminary discussion to establish a name for the animal and to call it to the attention of zoologists and others.

The Pit 11 fauna includes several other soft-bodied animals of uncertain systematic position, a variety of polychaete annelids, mollusks both naked and shelled, several eumalacostracan crustaceans, insects, primitive arthropods, a phyllocarid, a branchiopod, a xiphosuran, a holothurian, fishes, and amphibians. In contrast to the biota of the older collecting area, the fossils of Pit 11 and vicinity are predominantly animal; the plant remains found here are more fragmentary, but represent the same well-known flora. The Pit 11 fauna probably lived farther offshore

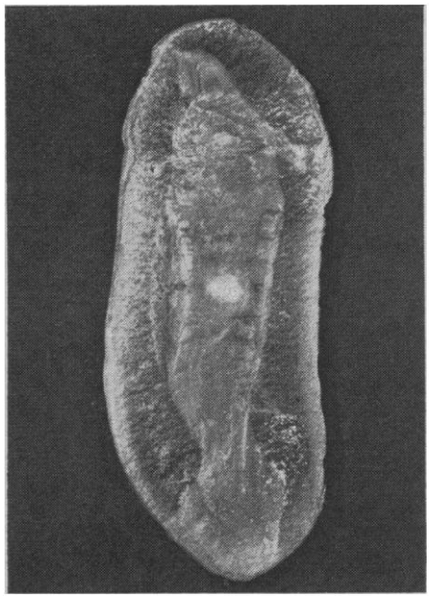

Fig. 1. The holotype of *Tullimonstrum gregarium*, new genus, new species. The specimen is nearly complete in a concretion 12 cm long. The proboscis is turned back across the head and the transverse bar. Chicago Natural History Museum No. PE 10504.

than the fauna of the other area, in shallow water broken by mud bars and low, unforested islands. Land plants and land animals were occasionally brought into this environment during high-water influxes from the deltaic coastal plain on the site of Mazon Creek and the older strip mines.

While this obscure but plentiful animal is being studied, I prefer not to assign it to a phylum. A great deal of anatomical detail may be deduced from the several hundred specimens on hand, but it must be carefully assessed if the biological relationships are to become clear.

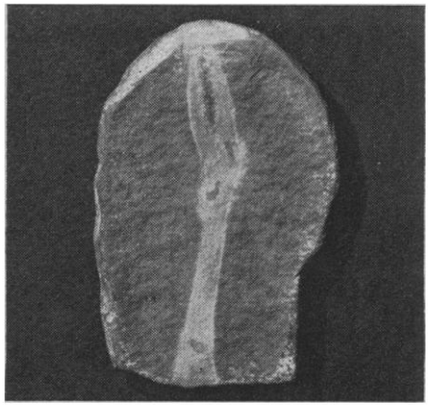

Fig. 2. Distal end of proboscis of *Tullimonstrum gregarium* in a concretion 5.8 cm long. Chicago Natural History Museum, No. PE 10505.

Tullimonstrum, new genus

Type: *Tullimonstrum gregarium*, new species. Since but a single species is recorded, the characterization of the genus must be the same as that of the species.

Tullimonstrum gregarium, new species

Diagnosis: The animal is bilaterally symmetrical, subcylindrical, 6 to 25 cm long, with an unsegmented head region, a segmented trunk, and a tail region. The head tapers abruptly to a long, flexible, anterior proboscis with internal teeth in a slot at the distal end, and is delimited from the trunk by a thin and relatively hard transverse bar that has an expanded portion in the middle and that bears on each end, beyond the body wall, a small, hollow, flattened globular organ. The trunk is composed of about 13 segments, many or all of which contain a round medial internal organ. In the tail region, the segmented body tapers gently to a blunt narrow termination and is flanked by a pair of thin, flexible, broad triangular flaps or fins.

Holotype: Chicago Natural History Museum (number PE 10504) (Fig. 1).

Discussion: Pending a more detailed report on the anatomy, I will discuss only the salient features of the animal.

1) *Proboscis* (Fig. 2). The flexible proboscis is, in many specimens, turned back across the front of the body, bringing its distal end to the transverse bar, but more commonly it extends straight out forward. Distally, it is slightly expanded, with a medial slot. Within the slot are several small, sharp triangular teeth or stylets, at least four on each side, arranged in opposing pairs. There is no trace of a central lumen extending through the length of the proboscis.

2) *Transverse bar and appended organs*. The most immediately recognizable feature of the Tully monster is the transverse bar. Even in the flattened condition of the fossils the bar is longer than the width of the body; in life it obviously projected well beyond the body wall on both sides, and the terminal organs were external. The bar was of harder material than the rest of the animal, since in all cases it leaves a sharp impression. In most specimens it lies directly athwart the body, but in a few it is slightly displaced laterally or rotationally, and in two instances a bar has been found free. A pyritized Tully monster etched free from the enclosing rock has a posteriorly directed enlargement at the mid-point of the bar; this is seldom clearly visible on impressions, suggesting that it was internal and of less sturdy construction than the rest of the bar. One specimen of a bent, probably fractured, bar is known. On each end of the transverse bar the small ovoid organ projects posteriorly and ventrally. These were hollow and somewhat flexible; in many impressions they contain conspicuous black particulate material.

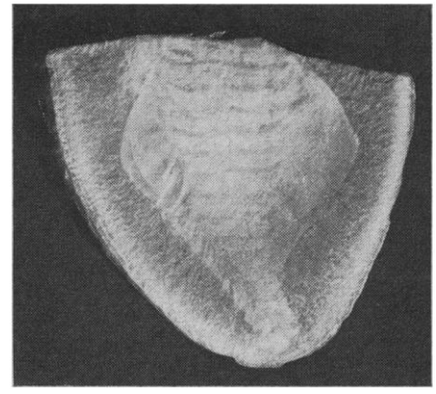

Fig. 3. Tail of *Tullimonstrum gregarium* in a concretion 6.7 cm long. Chicago Natural History Museum, No. PE 9407.

3) *Body*. The body was soft, without a chitinous or other stiff cuticle, and was composed of about 13 segments between the bar and the tail fins. Partly decayed specimens had begun to separate, segment from segment, before burial. No mouth or anus has been certainly observed on the body; a light-colored line extending from the transverse bar to about the tail of some specimens may represent a gut, or may be simply an external color marking.

4) *Tail* (Fig. 3). The lateral triangular fins were thin and mobile. Folds and creases in the outer edges suggest that they could sustain a rippling motion like that employed by a modern squid. The posterior end of the body, tapering to a small, blunt end, continues slightly beyond the tail fins. The body portion of the tail (not the fins) shows a pattern of transverse colored stripes, probably corresponding to body segments.

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References and Notes

1. E. S. Richardson, Jr., *Fieldiana: Geol.* **12**, 3–12 (1956).
2. A detailed report by R. G. Johnson and E. S. Richardson, Jr., is in preparation.

14 October 1965