are oriented parallel $b\{010\}$. These slabs are in turn joined along $b[010]$ by two kinds of independent tetrahedral units: $[Si_2O_7]$ corner-sharing pairs and $[(Al,Si)_2SiO_{10}]$ corner-sharing triplets (Fig. 1c). The interesting T_3O_{10} triplets are not new to science, being recently reported (*7*) in the crystal structure of ardennite; as in the ardennite structure, they utilize a mirror plane. The full kornerupine structure is a stable three-dimensional arrangement. Although apparently there are no limitingly close-packed layers of oxygen atoms, the structure evidently conserves space efficiently, since the volume per oxygen atom is 17.0 $Å^3$.

Metal-oxygen distances appear in Fig. 1c: Al-O octahedral distances average 1.91, 1.93, and 1.97 Å; Mg-O octahedra, 2.09 and 2.12 Å; Si-O tetrahedra, 1.62 and 1.63 Å; and (Al, Si)-O tetrahedra, 1.68 Å, with metal-oxygen distances ± 0.02 Å. The Mg(1)-O octahedron is highly distorted and must be considered separately in the crystallochemical formula. These Mg(1)-O octahedra join by reflection across $a\{100\}$ by way of hydroxyl (OH) groups. The crystallochemical formula is written

$$Mg^{VI}_2Mg^{VI}Al^{VI}_6[Si_2O_7][(Al,Si)_2SiO_{10}]O_4(OH)$$

of which there are four units in the structure cell. The multipliers and temperature factors assist in locating the minor-element substitutions. McKie's formula may be written

$$(Mg, Na)_2\,Mg\,(Al, Fe, Mg)_6\,[Si_2O_7]\,[(Al, Si)_2\,(Si, B)O_{10}]\,O_4\,(O, OH).$$

We present electrostatic valence-bond strengths in Table 3, computed according to Pauling (*8*). Deviations from saturation are slight, confirming the assignment of the metals on the basis of their interatomic distances. It is seen that O(10) must be a hydroxyl group; it accounts for the presence of water in the wet-chemical analyses reported for kornerupine.

Table 3. Electrostatic valence-bond strengths (ξ) in kornerupine.

Atom	Associated metals	ξ
O(1)	Al(3) + Mg(1) + Al(2) + Al(2′)	1.8
O(2)	Al(3) + Mg(2) + Al(4) + Al(4′)	1.8
O(3)	Si(1) + Al(3) + Mg(2)	1.8
O(4)	Si(1) + Mg(1) + Al(2) + Al(2′)	2.3
O(5)	(Al,Si)(1) + Mg(1) + Al(3)	1.7
O(6)	(Al,Si)(1) + Al(2) + Al(4)	1.9
O(7)	Si(2) + (Al,Si)(1) + Mg(1)	2.2
O(8)	Si(2) + Al(4) + Al(4′) + Mg(2)	2.1
O(9)	Si(1) + Si(1′)	2.0
O(10) = (OH)	Mg(1) + Mg(1′)	0.7

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References and Notes

1. J. Lorenzen, *Medd. Groenland* **7**, 19 (1884).
2. D. McKie, *Mineral. Mag.* **34**, 346 (1965).
3. Crystals supplied by D. McKie.
4. We thank J. V. Smith for help.
5. E. B. Fleisher, R. B. K. Dewar, A. L. Stone, in *Amer. Cryst. Assoc. Winter Meeting Progr. Abstr.* (1967), p. 20. We thank R. B. K. Dewar and S. Hawkinson for assistance in setting up this program.
6. J. Karle and I. L. Karle, *Acta Cryst.* **21**, 849 (1966) (a good introduction).
7. G. Donnay and R. Allmann, in *Amer. Cryst. Assoc. Summer Meeting Progr. Abstr.* (1967), p. 91.
8. L. Pauling, *The Nature of the Chemical Bond* (Cornell Univ. Press, Ithaca, N.Y., ed. 3, 1960), p. 547.
9. Supported by NSF grant GA 907 to P.B.M. and by Petroleum Research Fund grant 642-A2 to J.M.B. by American Chemical Society.

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Ten-Armed Fossil Cephalopod from the Pennsylvanian of Illinois

Abstract. Jeletzkya douglassae *Johnson and Richardson is described as the oldest known representative of an extant squid group. The species is known from a single specimen from the Middle Pennsylvanian of Illinois. This very unusual fossil consists of the complete tentacular crown and a fragile shell. The arms bear hooks in double rows.*

A new locality in the Mazon Creek area of northeastern Illinois is yielding an extensive and almost wholly undescribed fossil fauna consisting largely of soft-bodied marine animals (*1*). The fossils occur in ironstone concretions in the Middle Pennsylvanian Francis Creek shale. The fauna includes a variety of polychaete annelids, mollusks, crustaceans, jellyfish, and several animals of uncertain zoological affinities (*2*). Recently a member of the Earth Science Club of Northern Illinois collected a remarkable fossil decapod mollusk from this locality.

The specimen is preserved in a small ironstone concretion 61 by 52 mm in size. Part of the fossil is revealed on a plane of the concretion split open by the collector. The exposed portion consists of a crown of ten arms; a thin flat shell has been revealed by radiographs. Inasmuch as the ordinal position of this animal is uncertain, we have avoided designating the fossil by a name that might imply a particular zoological affinity (*3*).

Phylum Mollusca
Class Cephalopoda

Jeletzkya Johnson and Richardson, new genus

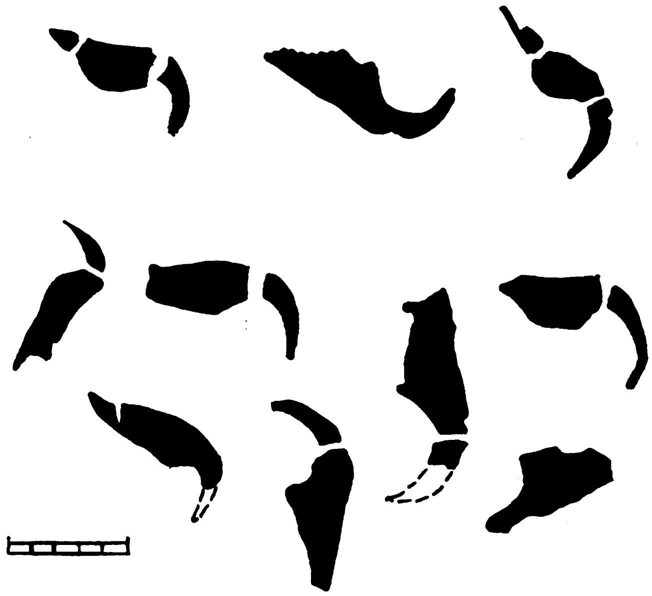
Type: *Jeletzkya douglassae* Johnson and Richardson, new species. As there is but a single specimen known, the characterization of the genus must be the same as that of the species.

Jeletzkya douglassae Johnson and Richardson, new species

Diagnosis: Decapod with a narrow, nearly flat shell lacking a chambered phragmocone but possessing a short conus. Shell simple, not differentiated into median field and wings. Arms of nearly equal length, provided with paired rows of arm hooks. Holotype and only known specimen, both halves of an ironstone concretion, number 565, in the collection of David Douglass, Western Springs, Illinois.

The tentacular crown of the only specimen known is 30 mm in diameter (see cover). The arms range from 9.5 to 10.5 mm in length and are 2.0 to 2.5 mm wide at their bases; maximum spread of the arms is 30 mm. Strewn along the arms are minute hooks (Fig. 1). Most of the arm hooks are displaced, but on several arms the position shows that they were originally in two rows (Fig. 2). There is no evidence of suckers. In the center of the tentacular crown is an oval, black, nearly flat area. The surface of this unknown structure is organic in appearance. One of our colleagues has suggested that it might be a relic of an ink sac. There is no evidence of jaws or a radula in either half of the concretion.

The shell (Figs. 3 and 4) is concealed within the concretion except where it was intersected on grinding down the outer surface of the concretion. The very small amount of shell material exposed shows that it is extremely thin and fragile. We decided not to prepare out the shell because of the danger of damaging it and the remainder of the fossil; instead we have studied it by single and stereo radiographs (*4*). The shell is about 23.5 mm in length and has a maximum width of 8.0 mm. A millimeter or so of the posterior tip of the shell was removed in grinding down the concretion for x-ray examination. The lateral and stereo radiographs show the shell to



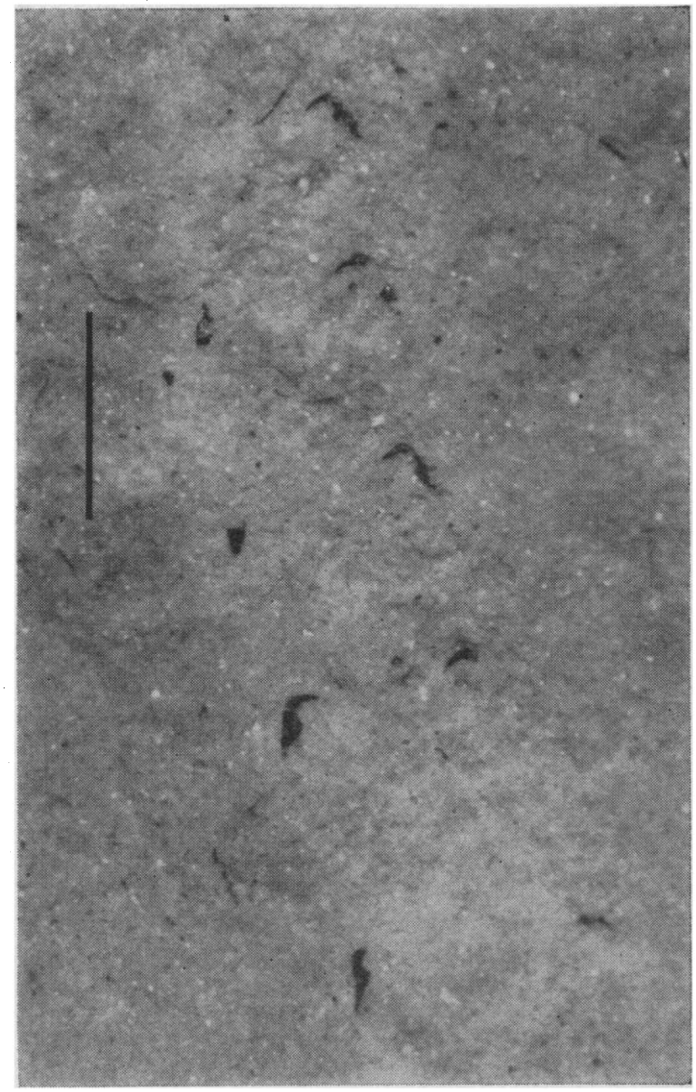
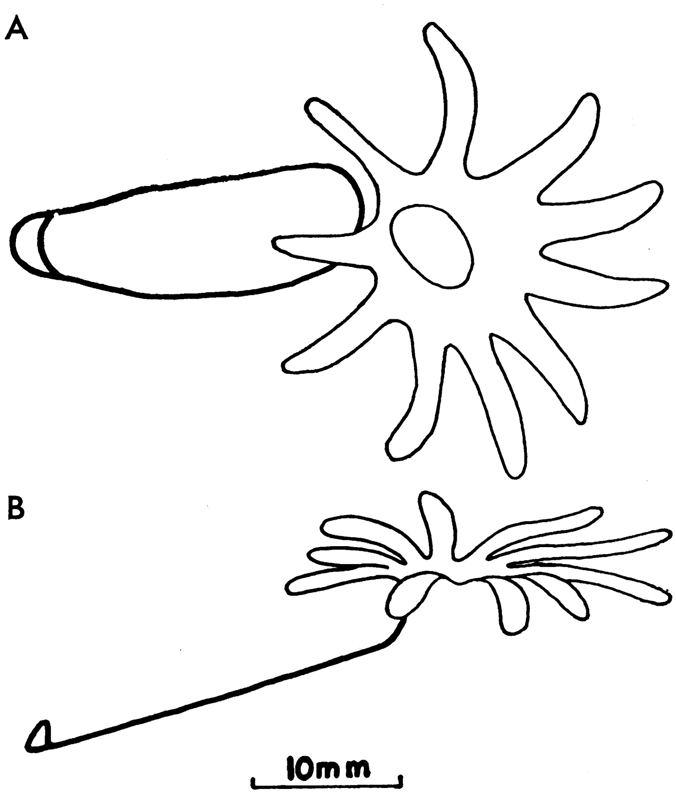


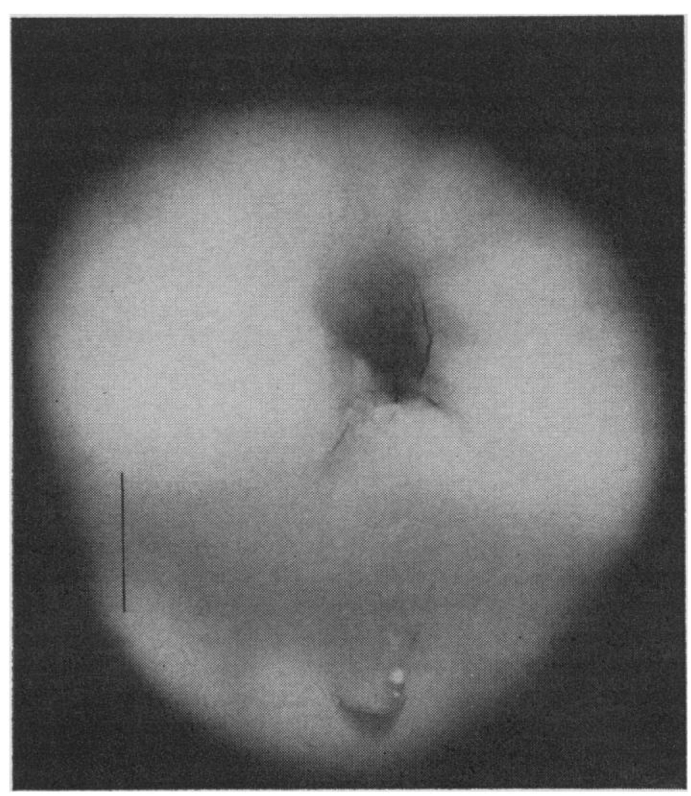
Fig. 1 (above). *Jeletzkya douglassae* Johnson and Richardson, new species. Tentacular hooks. Scale is ¼ mm in length.

Fig. 2 (right). *Jeletzkya douglassae* Johnson and Richardson, new species. Detail of arm showing hooks in two rows. Scale is 1 mm in length.

Fig. 3 (below left). *Jeletzkya douglassae* Johnson and Richardson, new species. (A) Ventral and (B) lateral view of the shell as reconstructed from radiographs.

Fig. 4 (below right). *Jeletzkya douglassae* Johnson and Richardson, new species. Radiograph showing shell within the ironstone concretion. Scale is 1 cm in length.





be flat and less than 0.5 mm thick throughout most of its length. The conus is 2.5 mm long and 4.0 mm wide across the anterior edge, and has a depth of 2.0 mm. No other features of the shell are evident. The radiographs (Fig. 4) show spots within the shell area, but spots of similar shape and density are also seen outside of the shell and are probably small bodies of pyrite. The shell appears to be complete but fractured.

The nature of the shell and its small size relative to the arm crown leave little doubt that the shell was internal, and that the animal was a coleoid. The presence of a small open conus and the lack of a phragmocone suggest that the shell may be a teuthid gladius. However, it appears not to be differentiated into median field and wings, as in the teuthids, nor are two of the arms modified as grasping tentacles, as in most teuthids and sepiids. Arms of essentially equal length, with hooks in double rows, are belemnite and phragmoteuthid characters, although the shell is unlike that of either of these groups.

If a teuthid or a sepiid, *Jeletzkya* is certainly the oldest representative of the modern squids, previously known from the Early Jurassic onward. The discovery of such a creature in the Paleozoic was anticipated by Jeletzky. In a recent monograph he stated his belief that "now-known taxa of fossil belemnite-like and teuthid Coleoidea, other than the Jurassic and Cretaceous belemnites proper, represent only a very small percentage of the taxa that actually lived in Middle to Late Paleozoic, Mesozoic and Cenozoic seas" (*5*).

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References and Notes

1. R. G. Johnson and E. S. Richardson, Jr., *J. Geol.* **74**, 626 (1966).
2. E. S. Richardson, Jr., *Science* **151**, 75 (1966).
3. We are pleased to honor one of the outstanding students of fossil Coleoidea, Dr. J. A. Jeletsky, and Mrs. June Douglass, the zealous amateur collector who has so generously made the specimen available to us.
4. We are grateful to Dr. Rainer Zangerl and Mrs. Ida Thompson for making the radiographs.
5. J. A. Jeletsky, *Univ. Kansas Paleontolog. Contrib., Mollusca*, Art. 7 (1966), p. 1.
6. Work reported here is included in the authors' Mazon Creek Project, supported in part by grant GB 5772 from the National Science Foundation.

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Solid-State Energy-Dispersion Spectrometer for Electron-Microprobe X-ray Analysis

Abstract. *Improved lithium-drifted silicon solid-state detectors allow detection and energy dispersion of x-rays of about 3 to 30 kiloelectron volts in the electron-microprobe x-ray analyzer. Energy resolution is sufficient to separate peaks of characteristic x-rays of elements adjacent in the periodic system at atomic number 20 and higher. The detected x-ray spectrum emitted from an unknown sample can be recorded with a multichannel analyzer in approximately 60 seconds.*

In electron-microprobe x-ray analysis, a focused electron beam is used to excite characteristic x-ray spectra in sample volumes of a few cubic microns; the intensity of the characteristic x-rays is a function of element concentration. For qualitative and quantitative elemental analysis, characteristic x-rays are selected with crystal x-ray spectrometers. These spectrometers separate the x-ray emission, according to wavelength, by diffraction from a crystal (wavelength dispersion) and commonly cover a wavelength range from about 1 to 88 Å (12 to 0.15 kev).

Detection and separation of x-ray spectra can also be achieved by use of energy-dispersion characteristics of certain types of x-ray detectors, where the amplitude of the detector output signal is proportional to x-ray photon energy. The main advantage of energy dispersion over wavelength dispersion is its ability to detect all lines in the emission spectrum simultaneously and with high photon-counting efficiency. Gas proportional detectors were first used for energy dispersion in electron-microprobe analysis by Dolby (*1*) and Birks and Batt (*2*). The method is limited by the resolution of the gas proportional detector — approximately 1.3 to 1.8 kev for CuK_α radiation. Resolution is defined as the width of the measured x-ray line at half the height of the peak above background.

Solid-state detectors with significantly higher resolution (1.1 kev) have recently been applied to x-ray photon counting (*3*). We now describe the application of such a detector (manufactured by ORTEC), having a resolution of 0.6 kev, to an ARL electron microprobe (*4*). This higher resolution substantially improves separation of characteristic x-ray lines in complex x-ray spectra, and line-to-background ratios.

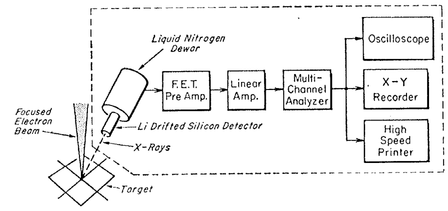

Fig. 1. Solid-state energy-dispersion spectrometer.

The solid-state energy-dispersion spectrometer (Fig. 1) consists of a cooled lithium-drifted silicon diode, a low-noise preamplifier (ORTEC 116), a linear amplifier (ORTEC 440), a multichannel (1024) analyzer (Nuclear Data 2200), and a high-speed printer (Franklin 1220). The detector and first stage of the preamplifier, cooled by liquid nitrogen, are mounted inside a separate vacuum chamber which is isolated from the main vacuum of the electron probe by a 0.125-mm beryllium window.

The detector is mounted in an existing x-ray port of the electron-microprobe analyzer, 25 cm from the target, at an x-ray emergence angle of 52.5 deg. The active area of the detector is 0.5 cm^2, with an active depletion depth of 2 mm. The preamplifier is a charge-sensitive field-effect transistor having low noise–high gain characteristics; it is closely coupled to the detector and provides gain to the detector signal and impedance matching to the linear amplifier. Gain and pulse shaping of the preamplified signal is accomplished by the linear amplifier. The amplified output signal from the linear amplifier is coupled to the analog-to-digital converter of a multichannel analyzer that processes pulses according to height (that is, energy) and stores them in the appropriate memory location. The stored energy spectrum can then be displayed on an oscilloscope screen for visual inspection, printed out on a high-speed printer, or plotted as an analog signal on an *x-y* recorder.

Performance of the solid-state energy-dispersion spectrometer (resolution and line-to-background ratio, sensitivity, and energy range) was evaluated with pure-element targets.