A FOSSIL SITE NEAR SULPHUR, INDIANA (CHESTERIAN, MISSISSIPPIAN)

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Some Terminology

The terms Konservat-Lagerstätten or Lagerstätten do not appear in Bates and Jackson (1987) and both terms have been transferred directly into English from the German paleontological literature. Seilacher (1970) did not comment on the origin of the term Fossil-Lagerstätten until he co-authored a subsequent review (Seilacher, Reif, and Westphal, 1985). Lagerstätten means literally resting-place and apparently appeared first as a technical word in the German mining literature where the term was associated with ore deposits (Heubner, 1939). Ores are economic deposits, that is, valuable commercial concentrations of a substance. Hence, Konservat-Lagerstätten are considered valuable sources of paleontologic information as the result of special conditions of preservation. In English the term "mother-lode" is used colloquially in a similar sense.

In the site discussed below, the finest preservation of fossils occurs at the tops of beds of limestone covered by shales. Shrock (1948, p. 307-310) referred to these types of occurrences as smothered bottoms. Although smothered bottoms are among the commonest of Konservat-Lagerstätten, they were apparently considered principally as enhancing reducing conditions of preservation in the sub-categories of Konservat-Lagerstätten originally defined by Seilacher (1970). Subsequently, Seilacher, Reif, and Westphal (1985) gave more attention to the physical conditions of the rapid burial (their term: obrution) sub-category of Konservat-Lagerstätten, which includes smothered bottoms. The most notable occurrences at this site are of echinoderms, especially crinoids and blastoids that exhibit entire crowns and extensive lengths of stem.

The Sulphur Site

An extensive exposure of Late Mississippian (early and middle Chesterian) rocks (Figure 1 and Table 1) is located at the junction of Interstate 64 and Indiana Highway 37 approximately 1 mile (1.5 km) north of Sulphur, Crawford County, Indiana on the Beechwood U. S. Geological Survey 7.5-minute topographic quadrangle (Horowitz and Kelly, 1987). The Reelsville-Elwren interval is best exposed on the southeast access ramp of the highway junction. The most extensive exposures are on the northeast corner of the highway junction

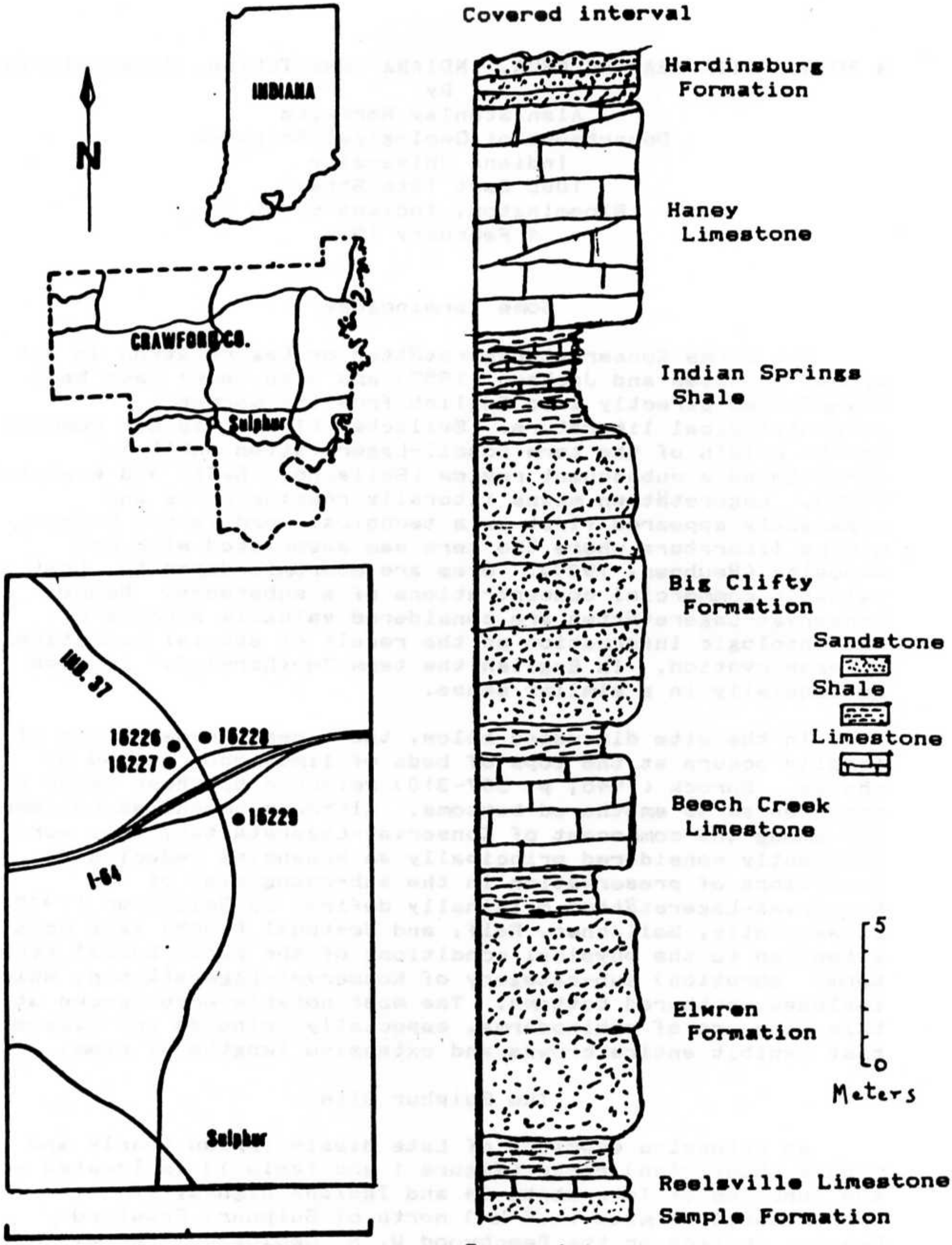

Figure 1. Geographic position (from Kelly, 1984) and graphic stratigraphic section of Sulphur site.

Table 1. Formations occurring in the roadcuts at the junction of Interstate Highway 64 and Indiana Highway 37.

Hardinsburg Formation
Haney Limestone
Indian Springs Shale (=Fraileys Shale)
Big Clifty Formation
Beech Creek Limestone
Elwren Sandstone (=Cypress Sandstone)
Reelsville Limestone
Sample Formation

approximately N1/2 S1/2 Sec. 24, T. 3 S., R. 1 W., which reveal at road level varicolored shales at the top of the Elwren Sandstone and the overlying Beech Creek Limestone. Highway construction has produced a series of benchs of which the highest is several meters wide and occurs within or at the top of the Indian Springs Shale. Excavations covering several square meters have been made along this bench by amateur and professional fossil collectors.

These exposures have been the focus of several theses at Indiana University and the work reported in the earliest theses was briefly summarized by Horowitz and Kelly (1987). The present discussion will be directed to the richly fossiliferous Indian Springs Shale (Kelly, 1984) that lies between the Big Clifty Formation below (Suttner and Visher, 1979; Visher, 1980a,b) and the Haney Limestone above (Foster, 1990). Most of the information presented below is based on the work of Kelly (1984).

In this area, the Indian Springs Shale is between 3 and 4 meters (10-13 feet) thick and consists of a predominantly shale lower interval and an interbedded limestone and shale upper interval. The lower shale interval is not very fossiliferous except near its top where a low diversity ostracode and molluscan (mostly pelecypod) fauna has been recovered. The source of the best preserved specimens is the richly fossiliferous upper interval of interbedded limestone and shale. Limestone beds in the Indian Springs range from feather edges up to 30 cm (1 foot) thick and are composed almost exclusively of fragmental calcareous skeletal debris of brachiopods, bryozoans, and echinoderms. These three groups were the dominant contributors to carbonate sands and coarser debris in the warm shallow seas that covered southern Indiana during late Mississippian time. Paleogeographic reconstructions indicate that southeastern Indiana was 5 to 10 degrees south of the equator at this time.

Diversity (also called disparity in Gould, 1989) of the fossils differs greatly between the two intervals within the Indian Springs Shale (Table 2). The entire unit contains

Table 2. Generic diversity for major groups of fossils within lower and upper intervals of the Indian Springs Shale. Data compiled from Kelly (1984). X=present.

	Lower Shale	Upper Shale and Limestone
Coelenterata	-	2
Echinodermata	1	26
Bryozoa	2	15
Brachiopoda	6	16
Mollusca	5	9
Arthropoda	6	10
Worm tubes	X	1
Vertebrata	X	18

nearly 100 genera of fossils. This is a minimun number because some groups have not received adequate taxonomic study.

Kelly (1984) interpreted both the individual life habits of the shelly fauna and the associations of species within the Indian Springs Shale (Table 3 from Kelly, 1984; Horowitz and Kelly, 1987). The dominant elements of the shelly fauna are the filter-feeding echinoderms, bryozoans, and brachiopods. Most of these forms are interpreted as living attached to the sea-floor (sessile benthos), but the stems of crinoids and blastoids may have functioned as grappling hooks so that they had some potential for being moved by currents and reattaching to the bottom if conditions changed.

The organisms living in the Indian Springs seas lived at various heights above the sea floor (Table 3). Low level feeders encrusted the bottom or they fed in approximately the lower 15 cm (6 inches) of the water column. Feeders at the intermediate level were elevated approximately 15-50 cm (6-20 inches) above the bottom and feeders at the highest level were more than 50 cm (20 inches) above the bottom. Feeding strategies were divided into suspension (typically filter) feeders, detritus feeders, and predators (Table 3). Clearly the most common groups of fossils fed on the smallest sizes of food (microphagous) found in the waters during deposition of the Indian Springs Formation. See Table 4 for a list of the fauna from this site.

Conway Morris (1979) indicated that the sessile benthos in the famous Middle Cambrian Burgess Shale probably fed from the bottom up to perhaps 20 cm above the bottom. Long before the Mississippian, sessile invertebrates had begun feeding higher and higher into the water column. Crinoid stems a meter or more long are known in mid and late Paleozoic shallow continental seas (Ausich and Bottjer, 1985).

Table 3. Summary of feeding strategies of fossils found in the Indian Springs Shale, near Sulphur, Indiana. *Phestia* and *Sanguinolites* are pelecypods; *Spirorbis* is a coiled encrusting calcareous worm tube; *Tubulelloides* is a straight phosphatic worm tube; *Archimedes* is the coiled (screw) bryozoan; *Onychocrinus* and *Taxocrinus* are crinoids.

Feeding Strategy	Suspension feeders: Microphagous	Suspension feeders: Macrophagous	Detritus feeders (browsers & scavengers)	Predators
Low (on or near bottom)	brachiopods, bryozoans *Sanguinolites* conularid *Spirorbis* *Tubulelloides*	cup corals	?scolecodonts, ?ostracods, trilobites, non-platycerid gastropods *Phestia*	?scolecodonts, ?ostracods cephalopods, vertebrates
Medium	blastoids, *Archimedes*, fenestrate fronds, short-stemmed crinoids	small *Taxocrinus*		cephalopods vertebrates
High	long-stemmed crinoids	large *Taxocrinus* and *Onychocrinus*		cephalopods vertebrates

Paleontologists are interested in the diversity of life through time. Commonly only forms possessing skeletons are preserved in the fossil record. In this connection, it is interesting to note that the generic diversity (disparity = 118) of the Burgess Shale, including all the soft-bodied forms, is approximately that of the shelled invertebrates in the late Mississippian Indian Springs Shale. Because soft-bodied forms are not known from the Indian Springs Shale or from any Chesterian rocks in the Illinois Basin (principally Illinois, Indiana and Kentucky), the diversity of life during the deposition of the Indian Springs Shale probably was greater than for a comparable site during the Middle Cambrian.

Rapid burial can permit some assessment of the community actually living at the time of burial as contrasted with associations due to current sorting and accumulation. However, detailed studies of individual limestone surfaces have not been recorded for this site, an indication that paleontologic studies are never complete. Additional data always will be needed to assess concepts receiving renewed interest, especially hypotheses testable with higher resolution by improved technology and more detailed collecting. Only a few published papers deal with this Indian Springs site. In addition to those works cited above, Welch (1976, 1978) has published on fossils from this locality.

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Table 4. Faunal list from Sulphur site compiled from Kelly (1984).

Foraminifera
- ?*Archaediscus* sp.
- ?*Calcivertella* sp.
- ?*Tetrataxis* sp.
- ?*Endothyra* sp.

Coelenterata
- *Zaphrentoides* (*Amplexizaphrentis*) *spinulosum* (Milne-Edwards & Haime)

Worms
- *Paraconularia chesterensis* (Worthen)
- *Spirorbis* sp. (three varieties)
- *Tubulelloides* sp.
- Worm "teeth" (scolecodonts)

Trilobita
- *Paladin chesterensis* (Weller & Weller)

Ostracoda
- *Amphissites* sp.
- *Cavellina* sp.
- *Cornigella golcondensis* (Croneis & Gale)
- *Geisina* sp.
- *Hypotetragona* sp.
- *Kirkbya* sp.
- *Polytylites biforatus* (Croneis & Thurman)
- *Polytylites quincollinus* (Harlton)
- *Polytylites suprus* (Croneis & Gale)

Brachiopoda
- *Anthracospirifer leidyi* (Norwood & Pratten)
- *Beecheria* sp.
- *Cleiothyridina sublamellosa* (Hall)
- *Composita trinuclea* (Hall)
- *Crania* sp. cf. *C. chesterensis* Miller & Gurley
- *Diaphragmus* sp.
- *Echinoconchus alternatus* (Norwood & Pratten)
- *Eumetria* sp.

Table 4 (continued)

Brachiopoda (continued)
- *Lingula* sp.
- *Orbiculoidea* sp.
- *Orthotetes* sp.
- *Ovatia* sp. cf. *O. ovata* (Hall)
- *Punctospirifer transversus* (McChesney)
- *Reticulariina spinosa* (Norwood & Pratten)
- *Schuchertella* sp.
- *Trigonoglossa* sp.

Bryozoa
- *Archimedes* sp.
- *Ascopora* sp. (two forms)
- *Callocladia* sp.
- *Cheilotrypa* sp.
- *Eridopora* sp.
- *Fenestella* sp.
- *Fistulipora* sp.
- *Hederella* sp.
- *Lyroporella* sp.
- *Meekopora* sp.
- *Polypora* sp.
- *Rhabdomeson* sp.
- *Septopora* sp.
- *Tabulipora* sp.
- *Thamniscus* sp.

Gastropoda
- bellerophontacean sp.
- *Borestus* sp.
- ?*Bulimorpha* sp.
- ?*Donaldina* sp.
- ?*Meekospira* sp.
- ?*Naticopsis* sp.
- *Orthonychia chesterense* (Meek & Worthen)
- ?*Stegocoelia* sp.

Cephalopoda
- *Stroboceras* (*Epistroboceras*) sp. cf. *S.* (*E.*) *texanum* (Miller & Youngquist)
- *Stroboceras* (*Stroboceras*) sp. cf. *S.* (*S.*) *cripsum* Gordon
- *Triptoceroides knighti* Miller & Furnish

Bivalvia (Pelecypoda)
- ?*Aviculopecten* sp.
- *Nuculopsis* sp.
- ?*Permophorus* sp.
- ?*Phestia* sp.
- *Sanguinolites* sp.

Echinodermata
- *Acrocrinus* cf. *A. constrictus* Burdick & Strimple

Table 4 (continued)

Echinodermata (continued)

Allagecrinus sp.
Agassizocrinus sp.
Aphelecrinus oweni Kirk
Archaeocidaris sp.
Camptocrinus cf. *C. multicirrus* Springer
Culmicrinus sp.
Cymbiocrinus sp.
Dichocrinus sp.
Diploblastus sp.
Harmostocrinus cf. *H. minuspiniferous* Strimple
Hyrtanecrinus inflatus Broadhead & Strimple
Hyrtanecrinus pentalobus (Casseday & Lyon)
Lepidesthus sp.
Lepidodiscus sp.
Neopalaester sp.
Onychocrinus pulaskiensis Miller & Gurley
Passalocrinus sp.
Pentaramicrinus bimagnaramus Burdick & Strimple
Pentremites sp. (at least 4 forms)
Phanocrinus sp.
Phacelocrinus longidactylus (McChesney)
Pterotocrinus rugosus Lyon & Casseday
Ramulocrinus milleri (Wetherby)
Taxocrinus cf. *T. whitfiledi* (Hall)
Tholocrinus discus Strimple
Tholocrinus cf. *T. spinosus* (Wood)
Tremataster sp.
Zeacrinites cf. *Z. wortheni* (Hall)

Taxa of Unknown Affinities

Cornulites sp. (conical encrusting tube)
Phosphanulus sp. (phosphatic crinoid stem infestor)
Turrilepas sp. (machaeridian)

Vertebrata

Acanthodian spines
Actinopterygian scales
Ctenopetalus sp.
Chomatodus sp.
Cladodus sp. (three forms)
Deltodus sp. (two forms)
Deltaptychius sp.
Fissodus sp.
Helodus sp.
?*Lissodus* sp.
Lophodus sp.
?*Orodus* sp.
Petalodus sp.
Platyxetrodus sp.
Pleurodus sp. (two forms)
?*Poecilodus* sp.

Table 4 (continued)

Vertebrata (continued)
- *Protacrodus* sp.
- *Psammodus* sp.
- *Psephodus* sp.
- *Pterodus* sp.
- rhizodontid sp.
- *Sandalodus* sp.
- *Tanaeodus* sp.

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