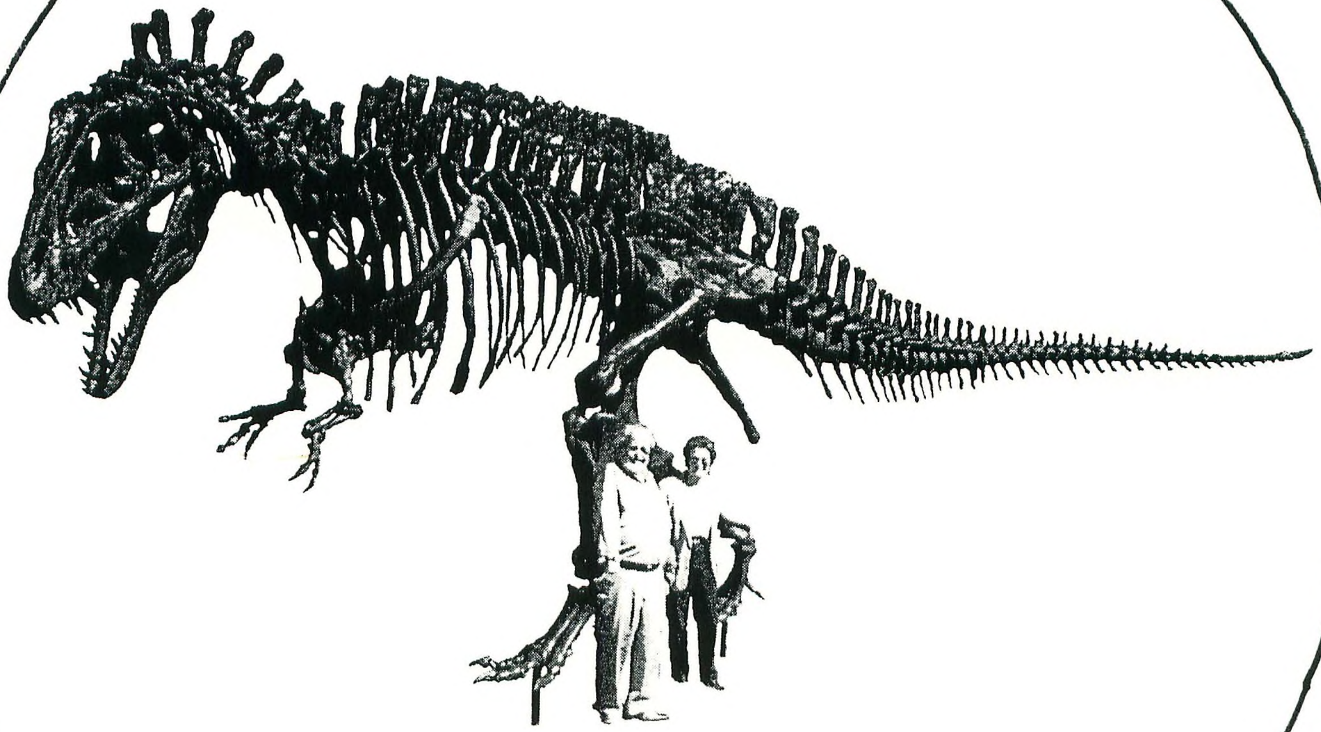
M·A·P·S Digest

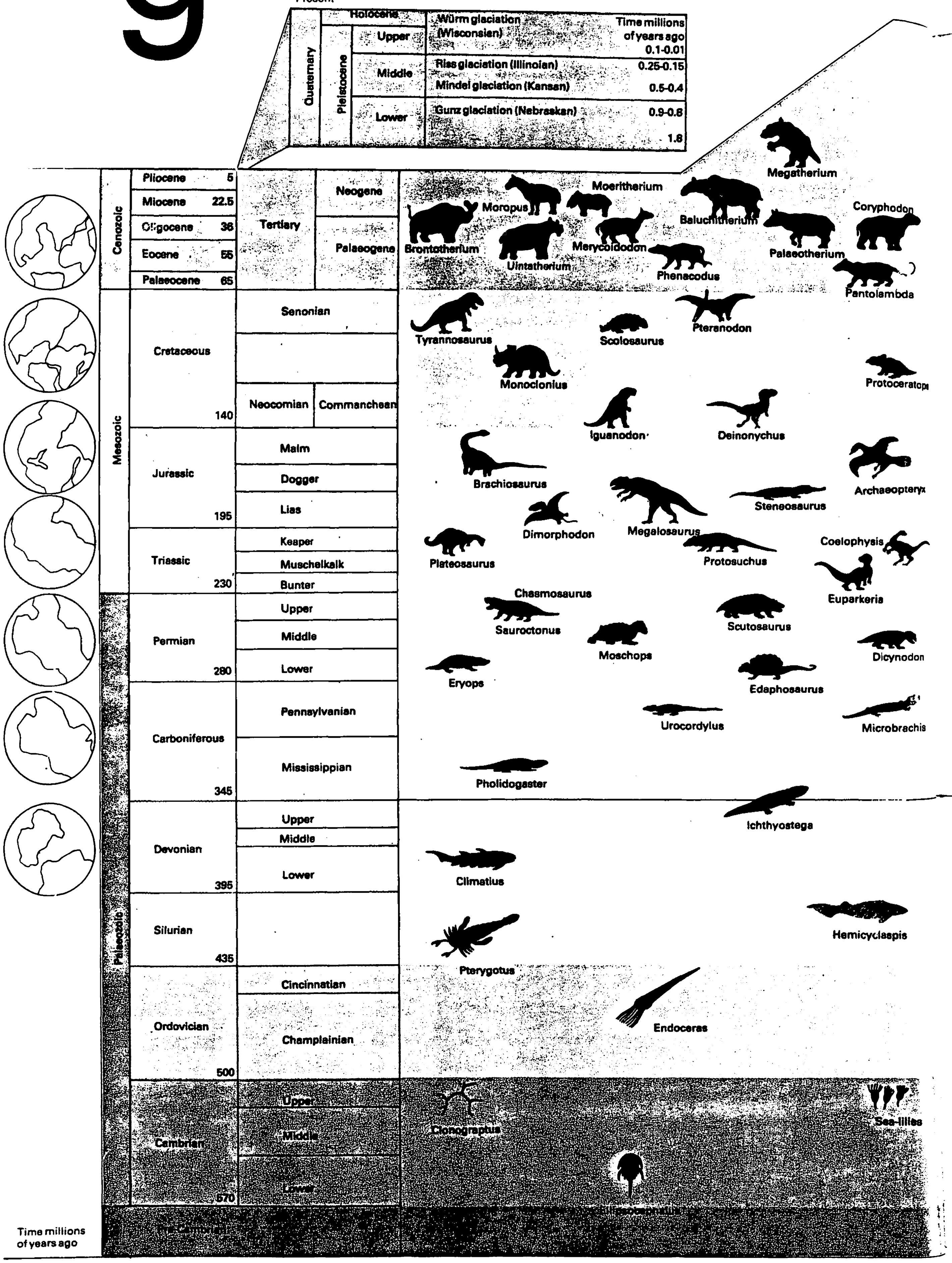
Official Publication of
Mid-America Paleontology Society

Volume 20 Number 4
EXPO XIX EDITION, 1997



FRAN

geological time chart



Present

				Time millions of years ago
Quaternary	Holocene			
	Pleistocene	Upper	Würm glaciation (Wisconsian)	0.1-0.01
		Middle	Riss glaciation (Illinoian)	0.25-0.15
			Mindel glaciation (Kansan)	0.5-0.4
		Lower	Gunz glaciation (Nebraskan)	0.9-0.8
				1.8

Cenozoic	Pliocene	5	Tertiary	Neogene
	Miocene	22.5		
	Oligocene	38		Palaeogene
	Eocene	55		
	Palaeocene	65		
Mesozoic	Cretaceous		Senonian	
		140	Neocomian	Commanchean
	Jurassic		Malm	
			Dogger	
		195	Lias	
	Triassic		Keuper	
			Muschelkalk	
		230	Bunter	
Palaeozoic	Permian		Upper	
			Middle	
		280	Lower	
	Carboniferous		Pennsylvanian	
		345	Mississippian	
	Devonian		Upper	
			Middle	
		395	Lower	
	Silurian	435		
	Ordovician		Cincinnatian	
		500	Champlainian	
	Cambrian		Upper	
			Middle	
		570	Lower	
Pre-Cambrian				

Time millions of years ago

EXTINCTION

MAPS DIGEST

EXPO XIX EDITION

MID-AMERICA PALEONTOLOGY SOCIETY

A LOVE OF FOSSILS BRINGS US TOGETHER

Western Illinois University
Union Ballroom
Macomb, Illinois 614665
April - 1997

ACKNOWLEDGEMENT

EXTINCTION

Evolution is the natural state; the balance of nature which we know as the ecosystem. Every living thing, plant or animal was put here on earth for a purpose.

What do you suppose the earth would look like today if it were not for the plants and animals which have become **EXTINCT**? Fossil fuels are derived from their organic remains, during the past eras. It is said the first forms of life have been found to be present in the Proterozoic Era (believe to be 4 1/2 billion years ago) in the form of coal. Coal is derived from the plants, the first stage being peat, the last stage is anthrasite.

THREATENED - ENDANGERED - EXTINCT, could be compared to a tornado, WATCH - WARNING - GONE THROUGH.

No species once **extinct** has ever reappeared. Some species thought to have become **extinct** have been found, because the environmental conditions where they were located preserved them or they learned to adapt to their surroundings. Numerous plants and animals have lived through many ages of geological time, while others have lived only a short time. It is doubtful if mankind will ever completely understand and know for sure why some species have become **extinct** while others remain untouched by the elements. All we know for sure is: were it not for evolution and the environmental changes, leading to **extinction** where or how would we be able to collect fossils, "perish the thought," strictly from an amateur's point of view. It will probably remain one of the mysteries of life--or is it death? ?

I wish to acknowledge, with greatful appreciation the **authors** and **artists** for sharing their knowledge and experitise with the rest of us. We, the members of **M.A.P.S.** have been inspired by their articles.

I also wish to thank the officers of **M.A.P.S.** for their support in my endeavor to be editor of this publication.

This issue, the EXPO EDITION of MAPS DIGEST is dedicated to Pete Larson and others at the Black Hills Institute, and our sympathy to "Sue".

The Mid - America Paleontology Society was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

Marvin Houg
President, M.A.P.S.
3330 44th Street NE
Cedar Rapids, IA 52402

Dale Stout
1st Vice President
2237 Meadowbrook Dr.SW
Cedar Rapids IA 52403

Karl Stuekerjuergen
2nd Vice President
1503 265th Avenue
Westpoint, IA 52656-9029

Alberta Cray
Secretary
1125 J Avenue NW
Cedar Rapids, IA 52405

Sharon Sonnleitner
Treasurer
4800 Sunset Dr., SW
Cedar Rapids, IA 52404

Dale Stout
Membership
2237 Meadowbrook Dr.SW.
Cedar Rapids, IA 52403

Sharon Sonnleitner
MAPS DIGEST EDITOR
4800 Sunset Dr., SW
Cedar Rapids, IA 52404

Karl Stuekerjuergen
Show Chairman
1503 265th Avenue.
West Point, IA 52656

Margaret E. Kahrs, Editor
EXPO XIX EDITION MAPS DIGEST
9145 W U.S. Hwy. 50 East
Seymour, IN 47274 - 9104

COVER STORY

ACROCANTHOSAURUS ATOKENSIS named Fran from Oklahoma.

The Front Cover of this issue of the **EXPO XIX EDITION of the Digest** features a photo of Fran and Allen Graffham standing beside their dinosaur.

The Back Cover is a photo of the skull.

Dinosaurs are extinct, or are they? Most scientists now believe that birds are living dinosaurs. Those most resembling dinosaurs are the larger flightless birds which look like dinosaurs in many ways.

Our *Acrocanthosaurus* is the only known essentially complete skeleton. This was found and excavated over a period of three years by Cephis and Sid Love from a site on the bank of the Red River in McCurtain County Oklahoma. This was the first dinosaur they had experienced but they did a fine job of excavating the skeleton and skull, which is considered to be one of the finest dinosaur skulls ever found.

While excavating took all of Sid and Cephis' time for three years, preparation and restoration went on for a total of seven years at the Black Hills Institute of Geological Research in Hill City, South Dakota. The Institute did a magnificient job of preparation, molding and casting of this dinosaur. Some bones were compressed (collapsed) and had to taken apart and then reassembled in the correct shape. The skull is somewhat compressed but this was not inflated. Instead casts were taken from both sides of the skull, and the casts were then inflated so that we now have a complete 3D skull and lowers for the mount of the cast.

The *Acrocanthosaurus* was named for Fran Graffham for her contribution to saving this magnificient dinosaur for science. Naming of each major dinosaur is traditional with Black Hills Institute and we continue with this tradition.

There was a problem with marcasite on the bones and especially the skull. this has all been removed and we feel the skeleton is now stable and in no danger from "pyrite disease". The actual skeleton and skull are now stored in a heat and humidity controlled room at the Black Hills Institute. The skeleton on the cover is a cast and this particular one is now in a traveling exhibition that will tour the United States for the next three years and then possibly be taken overseas for viewing. Eventually this exhibit will find a home in a permanent museum in the U.S. A second cast will be on display here in southern Oklahoma at the Goddard Youth Camp in the new Childrens Museum. This should be completed within the next year.

Geological Enterprises purchased the dinosaur skeleton in 1988 and it was immediately transported to Hill City, South Dakota. The unveiling of the first mounted cast was on September 8, 1996, held at Hill City and the event was attended by approximately 200 people.

What is unique about the *Acrocanthosaurus* is the row of spines starting at the head and going all the way along the back. These apparently were for muscle attachment, which would indicate an extremely strong animal. The arms are built much stronger than in *Tyrannosaurus* and have three fingers as opposed to *Tyrannosaurus rex's* only two.

The *Acrocanthosaurus* is 40 feet long and 10 feet high. This is along the same size line as an average *Tyrannosaurus.* The *Acrocanthosaurus* skull is 4 feet 7 inches long, 2 feet wide and 30 inches tall. The 68 teeth are unlike *Tyrannosaurus* in that they are flatter and built more like steak knives. The teeth are very much like *Carcharodontosaurus* and apparently it is very closely related to this dinosaur and also the Jurassic Allosaurus which was most likely its ancestor.

Acrocanthosaurus probably fed on sauropods and other dinosaurs it caught. The Glen Rose trackways near Glen Rose, Texas are those of *Pleurosaurus* being stalked by *Acrocanthosaurus* looking for a meal.

While this dinosaur is little known just now there will be a lot of papers written in the near future and someday this dinosaur will be as well known as *Tyrannosaurus rex.*

Table of Contents

MAPS DIGEST EXPO XIX EDITION - EXTINCTION

* denotes M.A.P.S. members

3/1/97

LEARNING FROM HISTORY:

MASS EXTINCTION IN THE PAST, PRESENT, AND FUTURE

Warren D. Allmon

Paleontological Research Institution
1259 Trumansburg Road
Ithaca, NY 14850

Those who do not learn from history are bound to repeat it. -- George Santayana

Students in introcutory geology or Earth science classes are often told that "the present is the key to the past". It is indeed true that our studies of present geological and biological processes and events are essential to our understanding of what happened in the past, when we were not there to see it. Less often, however, are we told how the past may be the key to the present, or even the future. This may well be the case in the subject of mass extinction.

These days, when endangered species are commonly featured on CNN and dodos are featured in best-selling books, it is easy to forget some basic facts in the history of science.

Extinction itself was discovered by a paleontologist. The great French scientist Georges Cuvier announced in the 1790's that, based on his comparison of fossil and living elephants, several distinct kinds elephants had once existed and now were no longer known alive. (Cuvier chose elephants because, even though there were many areas still to be explored by Europeans, it was unlikely that an animal the size of an elephant could go undiscovered and unreported. Prior to Cuvier, it had been difficult to conceive of extinction, because it implied that a species made by the Creator had been in some way imperfect.

Mass extinction -- the disappearance of relatively large numbers of species during relatively short short intervals of time -- was also discovered by paleontologists. Indeed, it is one of the cardinal features of the geological record. The most recent part of the geological time scale, the interval covering the last 540 million years or so that we now call the Phanerozoic, is divided into three parts or eras because of mass extinctions. In the early nineteenth century, when geologists and paleontologists first began to reconstruct the sequence of fossils that can be found in superposed strata of rocks, they quickly recognized that the lower layers contained fossils quite different from those of the middle layers which in turn were quite distinct from those of the upper layers. They initially called these three packages of fossiliferous rocks "Primary", "Secondary", and "Tertiary"; today we call them "Paleozoic", "Mesozoic", and "Cenozoic". Because (like all other divisions of the Phanerozoic time scale), the eras are defined by their distinct assemblages of fossils, the boundaries between them by definition mark intervals of dramatic change between these assemblages. We now recognize these intervals as times during which large numbers of species became extinct during (geologically-speaking) relatively short time spans, and we call them "mass extinctions".

Thus paleontology already long ago taught us something fundamental about life -- it becomes extinct from time to time. Beginning in the middle of the nineteenth century, non-paleontologists began to recognize that extinction was something that could also happen today. Stellar's sea cow, the great auk, the Caribbean monk seal, and, very nearly, even the American bison (just to choose a few examples), all disappeared in the nineteenth century. Concern over these and many other events eventually contributed to the rise of the conservation movement and the scientific field of conservation biology. The subjects of these pursuits have clear implications for the present and future state of the world and humanity's place in it. Paleontology, however, was not involved.

Paleontologists continued to study extinction, of course. But, by definition, paleontology is about the past, and almost all of the enormous quantity of research done by paleontologists on extinction has been about events in the past. Which raises a question: if extinction is so important for our present and our future, does paleontology, the field that discovered extinction, have anything to tell us that might help us understand the present and future of extinciton on this planet?

Yes.

An understanding of life's history is absolutely vital to an understanding of life's present, and its future. Paleontologists can make unique and specific intellectual contributions to understanding the problem of extinction in the present and to the prevention, or at least management, of extinction in the future. These contributions are, furthermore, ongoing and continuous, not just simple statements made once and for all. (For additional discussion of these issues, see Eldredge, 1991, 1995; Ward, 1994; and Leakey and Lewin, 1995.)

PRESENT EXTINCTIONS

Despite occasional statements to the contrary (e.g., Sedjo and Clawson, 1983; Simon and Kahn, 1984; Levine, 1989; Easterbrook, 1995), the evidence is overwhelming that the Earth is in the early phases of what promises to be, if current trends continue, an extinction episode of enormous, perhaps even geological, scale (e.g., Simberloff, 1986; Ehrlich, 1995). This situation is due almost completely to massive habitat alteration, with smaller contributions from direct taking (e.g., hunting and fishing) (Myers, 1979; Ehrlich and Ehrlich, 1981; Kaufman, 1986). Estimates of rates of current extinction are exceedingly difficult to make (Wilson, 1988; Lawton and May, 1995). Although we may not now be experiencing extinction rates equal to those of paleontologically known mass extinctions (Jablonski, 1995), some studies suggest that one half of the species of birds and mammals on Earth could be extinct within 30-130 years (Ehrlich, 1995), which would clearly rank as one of the great crises in the history of life. Even if these estimates were to moderate by several orders of magnitude, it would still be a geologically significant event.

THE PALEONTOLOGICAL CONTRIBUTION

Alone among the fields of human enterprise, paleontologists are the keepers of the knowledge of the history of life. They are not the only group of scientists increasingly convinced that we are in the early stages of the loss of a major proportion of the world's biological diversity, but they are the only one of those groups with direct access to knowledge about the short and long term effects of such losses. Paleontologists can say, with some justification, that they have, in effect, run this experiment before; more precisely, they have studied the consequences of nature having run it before. Paleontologists know what the world looks like after 50% or more of the world's species disappear in a relatively short period (such as happened at the end of the Cretaceous period).

As a consequence of their unique perspective atop geological time, paleontologists have specific insights that others involved in biodiversity research do not, and these insights matter to a full understanding and successful mitigation of impending human-mediated extinctions. Simply put, "mass extinctions in the fossil record have compelling implications for the plight of today's wildlife and for the survival of the human species" (Jablonski, 1986b:58).

What exactly are these "compelling implications?

1) Extinction is forever. This truism is more profound that it would first appear. Evolution is not a short order cook; it does not inevitably manufacture what the environment demands. It is a fundamentally historically contingent process and its products are unique. Thus "Once a species is extinct or a network of interacting species falls apart, it is gone forever" (Jablonski, 1986b: 58). The fossil record is the only source of this information.

2) The tropics are especially vulnerable. Tropical species appear to have suffered disproportionately during at least some mass extinctions in the past (Stanley, 1984, 1986). There may be a number of reasons for this -- from the biogeographic fact that when temperatures decline in the tropics there is no place to run, to hypotheses that narrower geographic ranges or ecological niches in tropical species make them preferentially susceptible to environmental disturbance. We might have figured this out without the fossil record, just by looking at the geographic patterns of current extinction, except that these patterns are also influenced by the geography of socioeconomics, demographics and development (e.g., Myers, 1979; Mares, 1986).

3) Destruction and extinction may be rapid, but recovery is slow. Rates of mass extinction evidently vary, both with the episode and the taxonomic groups examined, from geologically instantaneous (perhaps in the case of many groups at the K-T; e.g., Ward, 1990) to protracted over millions of years (in the case of the Permian-Triassic (e.g., Erwin, 1993) and the Eocene-Oligocene (Prothero, 1994) events). In all cases, however, recovery of diversity after an episode of substantial extinction is not rapid (Hart, 1995).

This is a uniquely paleontological conclusion. It is an important retort against the comment (that is still heard with amazing frequency; see Gould (1993) for discussion of a recent example) that since extinction is "natural" and even necessary for additional evolutionary diversification to occur, the current wave of extinctions should be of no special concern.

5) Mass extinction may fundamentally alter the shape of the biosphere. The degree to which mass extinction operates as an discrete level of the evolutionary process (e.g., Gould, 1985), overriding patterns produced during "normal times", is still debated (e.g., Raup, 1991). Yet it is clear that at the very least, by the vary magnitide and rapidity that define it, mass extinction acts as a very strong dose of historical contingency, which alters the constitution of the subsequent biota. Mass extinction is an unexpected interruption to the normal course of events; it changes things in unpredictable ways; it cannot be prepared for or adapted to. It removes species that might have been well adapted otherwise; it preserves species that might have been on their way out. The world after mass extinction is thus not just the world minus what disappeared; it is a qualitatively different place (Benton, 1986; Jablonski, 1986a; Hart, 1995).

This is a uniquely paleontological perspective, one that suggests that the current biodiversity decline will not just reduce diversity, but will redirect evolution in basic and unpredictable ways. By causing a mass extinction, in other words, humans are altering forever and significantly the course of the evolution of life on Earth (Myers, 1985, 1990; Ward, 1994).

6) Mass extinction results from "ecosystem collapse", via the "change of size and location of habitat" due to global climate change (e.g., Eldredge, 1991). Mass extinction is not just the summing of a lot of individual species gradually dwindling down to nothing, each for its own reasons. It is produced by the massive alteration of large areas of habitat. We would not know this

without paleontology; "the fossil record provides our only empirical data on what happens when biological communities collapse or disassemble" (Jablonski, 1995:39). This has the important implication for conservation that preservation of large numbers of species can best be achieved by preserving habitats rather than individual species. This is not a uniquely paleontological perspective (see, e.g., Ehrlich and Ehrlich, 1981), but one to which paleontological research can contribute significant new insights (e.g., Ricklefs et al., 1990; Brett, 1995; Morris et al., 1995).

7) Mass extinction is selective. Selectivity, the phenomenon of some kinds of organisms becoming extinct while others do not, is one of the most obvious aspects of mass extinction. It is certainly not discovery (see, e.g., Kitchell et al., 1986; Kitchell, 1990); it has recently been the subject of considerable debate in connection both with various "killing scenarios" associated with possible impact events at mass extinction boundaries (e.g., Jablonski, 1990) and with their critics (e.g., Archibald, 1996). Its role in shaping the subsequent biosphere, and its application to conservation biology, however, have been less emphasized, especially in the context of a continuing contribution of knowledge. It is here, however, that paleontologists can make a unique and continuing contribution of information and insight into the problems of conserving biodiversity today, and this promises to be an area of active and fruitful future research.

We are still largely ignorant of the ecology across mass extinction boundaries, of the anatomy (and thus the proximal causes) of ecosystem collapse going in and coming out of these events. We still do not really know in most cases why particular taxa become extinct -- in other words, the causal basis for the observation that mass extinction sorts out in sometimes predictable and sometimes unpredictable ways who will be the progenitors of the future. Ecology may matter and it may not. What we need to know is more natural history of taxa, communities and ecosystems that do and do not become extinct.

Table 1 is a very crude summary of some of the specific conclusions on selectivity that are currently present in the literature.

8) Communities are structured, breakdown, and recover in a variety of ways. Despite recent efforts by ecologists to extend their studies into longer timescales, studies of modern ecosystems will never have access to truly "evolutionary" time scales. Paleontology does, but of course sacrifices temporal resolution in the process. Nevertheless, paleontological evidence can and has been used to address the issue of how are ecosystems put together, taken apart, and put back together after a catastrophe (i.e., what types of environmental changes lead to changes in the composition of communities?). Paleontological data are, in fact, the only source of such insights.

At least some paleontological evidence has suggested that ecological communities do not respond as units to environmental change. Fossil data from pollen, beetles and vertebrates "show that species are highly individualistic in their behavior, so that few, if any, modern terrestrial communities existed in their present form 10,000 years ago. Instead, they originated in piecemeal fashion by means of shifts in abundance or geographic range of their constituent species and will presumably continue to change composition in response to anthropogenic or natural climatic changes" (Jablonski, 1991; see also Coope, 1995).

On the other hand, more recent ideas connected with the theory of "coordinated stasis" (Brett, 1995; Brett and Baird, 1995) suggest that communities and ecosystems may have considerable integrity in the face of environmental change over relatively long time scales, changing only when some environmental threshold is reached (Morris et al., 1995; DiMichele and Phillips, 1996). Which is it, and under what circumstances? We do not know yet.

What is the conservation value of this sort of information?

If it is indeed the case, as seems inevitable, that we will not be able to conserve all of the species now threatened by human activities with extinction (e.g., Myers, 1988), choices will have to be made. In such an eventuality, it may make an important difference whether or not particular aspects of individual ecology (i.e., "natural history") matter in determining extinction probability or susceptibility. Data from studies of who goes extinct and who survived previous episodes of mass extinction may allow paleontologists to make reliable (and much more specific) estimates of what types of species have a better chance of surviving under particular environmental conditions, what types need immediate protection, and what types are too far gone or will be prohibitively expensive to protect adequately. This might be particularly relevant in the marine realm, which is especially poorly known (Ray, 1988, 1991; Vermeij, 1989). In a world of limits, this is potentially very important information. Specific programs, of the sort that to my knowledge do not currently exist, could be established to funnel such information directly to the conservationists who need it most. Selectivity data and conclusions are already available out there in the everyday taxonomic, biostratigraphic and/or paleoecological work of many paleontologists. They have not, however, found their way as a matter of practice into the discourse of conservation biology.

CONCLUSIONS

I once heard a history professor tell his class, "history isn't WAS; history is IS". Neither the field of human history nor paleontology is solely about the past; they are and must be also about the future. Fossils are the now-dead remains of once-living organisms from times long ago. They fascinate us because of their antiquity, their strangeness, their beauty, their rarity, or the simple unlikeliness of their preservation. But they are also messengers; they bear information about what has happened to life on this planet at specific times in the past when the environment has changed enormously and quickly, too enormously and too quickly for life to respond. We have the ability to use this information to concoct generalizations about how life responds to environmental change. Although we cannot see the future with certainty, we can learn from the past to make informed predictions. It is incumbent upon all of us to do so. The present status of the Earth's store of biodiversity is not good; we ignore these messengers from the past only at the peril of the future.

REFERENCES

Archibald, D., 1996, Dinosaur extinction and the end of an era. What the fossils say. Columbia University Press, New York, 237 p.

Benton, M., 1986, The evolutionary significance of mass extinctions. Trends in Ecology and Evolution, 1(5): 127-130.

Brett, C.E., 1995, Stasis: life in the balance. Geotimes, 40(3): 18-20.

Brett, C.E., and Baird, G., 1985, Coordinated stasis and evolutionary ecology of Silurian to Middle Devonian faunas in the Appalachian Basin. *In* New approaches to speciation in the fossil record. D.H.Erwin and R.L.Anstey, eds., Columbia University Press, New York, pp. 285-315.

Buffetaut, E., 1990, The relevance of past mass extinction to an understanding of current and future extinction processes. Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section), 82:169-174.

Clemens, W.A., 1982, Patterns of extinction and survival of the terrestrial biota during the Cretaceous/Tertiary transition. *In* Geological implications of impacts of large asteroids and comets on the Earth. L.T.Silver and P.H. Schultz, eds., Geological Society of America Special Paper 190, pp. 407-414.

Coope, G.R., 1995, Insect faunas in ice age environments: why so little extinction? *In* Extinction rates. J.H.Lawton and R.M.May, eds., Oxford University Press, New York, pp. 55-74.

DiMichele, W.A., and T.L.Phillips, 1996, Climate change, plant extinctions and vegetational recovery during the Middle-Late Pennsylvanian transition: the case of tropical peat-orming environments in North America. *In* Hart, M.B., ed., Biotic recovery from mass extinction events. Geological Society Special Publication 102, The Geological Society, London, pp. 201-222.

Easterbrook, G., 1995, A moment on Earth. Viking Press, NY, 745 pp.

Ehrlich, P., 1995, The scale of the human enterprise and biodiversity loss. *In* Extinction rates. J.H.Lawton and R.M.May, eds., Oxford University Press, New York, pp. 214-226.

Ehrlich, P., and Ehrlich, A., 1981, Extinction. Random House, New York, 305 p.

Eldredge, N., 1991, The miner's canary. Unraveling the mysteries of extinction. Princeton University Press, Princeton, NJ, 246 p.

Eldredge, N., 1995, Dominion. Can nature and culture coexist? Henry Holt, New York, 190 p.

Erwin, D.H., 1993, The great Paleozoic crisis. Life and death in the Permian. Columbia University Press, New York, 327 p.

Hart, M.B., ed., 1995, Biotic recovery from mass extinction events. Geological Society Special Publication 102, The Geological Society, London, 394 p.

Jablonski, D., 1986a, Background and mass extinctions: the alternation of macroevolutionary regimes. Science, 231:129-133.

Jablonski, D., 1986b, Mass extinctions: new answers, new questions. *In* The last extinction. L.Kaufman and K.Mallory, eds., MIT Press, Cambridge, MA, pp. 43-62.

Jablonski, D., 1990, Mass extinction: extra-terrestrial causes. In Palaeobiology. A synthesis. D.E.G.Briggs and P.R.Crowther, eds., Blackwells, Oxford, pp. 164-170.

Jablonski, D., 1991, Extinctions: a paleontological perspective. Science, 253: 754-757.

Jablonski, D., 1995, Extinctions in the fossil record. *In* Extinction rates. J.H.Lawton and R.M.May, eds., Oxford University Press, New York, pp. 25-44.

Jablonski, D., and Raup, D.M., 1995, Selectivity of end-Cretaceous marine bivalve extinctions. Science, 268:389-391.

Kauffman, E.G., and Erwin, D.H., 1995, Surviving mass extinctions. Geotimes, 40(3): 14-17.

Kaufman, L., 1986,Why the ark is sinking. *In* The last extinction. L.Kaufman and K.Mallory, eds., MIT Press, Cambridge, MA, pp. 1-42.

Kitchell, J.A., 1990, Biological selectivity of extinction. *In* Extinction events in Earth history. E.G.Kauffman and O.H.Walliser, eds., Springer-Verlag, Berlin, pp. 31-43.

Kitchell, J.A., Clark, D.L., and Gombos, A.M., Jr., 1986, Biological selectivity of extinction: a link between background and mass extinctions. Palaios 1(5): 504-511.

Lawton, J.H., and May, R.M., eds., 1995, Extinction rates. Oxford University Press, New York, 233 p.

Leakey R., and Lewin, R., 1995, The sixth extinction. Patterns of life and the future of mankind. Doubleday, New York, 271 p.

Levine, N., 1989, Evolution and extinction. Bioscience, 39(1):38.

Mares, M.A., 1986, Conservation in South America: problems, consequences and solutions. Science, 233: 734-739.

Morris, P.J., Ivany, L.C., Schopf, K.M., and Brett, C.E., 1995, The challenge of paleoecological stasis: reassessing sources of evolutionary stability. Proceedings of the National Academy of Sciences, 92: 11269-11273.

Myers, N., 1979, The sinking ark. Pergamon Press, Oxford, 307 p.

Myers, N., 1988, Tropical forests and their species: going, going ... ? *In* Biodiversity. E.O.Wilson, eds., National Academy Press, Washington, DC, pp. 28-35.

Myers, N., 1990, Mass extinctions: what can the past tell us about the present and the future? Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section), 82:175-185.

Prothero, D., 1994, The Eocene-Oligocene transition. Paradise lost. Columbia University Press, New York, 291 p.

Ray, G.C., 1988, Ecological diversity in coastal zones and oceans. *In* Biodiversity. E.O.Wilson, eds., National Academy Press, Washington, DC, pp. 36-50.

Ray, G.C., 1991, Coastal-zone biodiversity patterns. Bioscience, 41(7): 490-498.

Raup, D.M., 1991, A kill curve for Phanerozoic marine species. Paleobiology, 17(1): 37-48.

Ricklefs, R.E., Buffetaut, E., Hallam, A., Hsu, K., Jablonski, D., Kauffman, E.G., Legendre, S., Martin, P., McLaren, D.J., Myers, N., and Traverse, A., 1990, Biotic systems and diversity -- Report of Working Group 4, Interlaken Workshop for Past Global Changes. Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section), 82:159-168.

Sedjo, R.A., and Clawson, M., 1983, How serious is tropical deforestation? Journal of Forestry, 81: 792-794.

Sheehan, P.M., and Hansen, T.A., 1986, Detritus feeding as a buffer to extinction at the end of the Cretaceous. Geology, 14: 868-870.

Simberloff, D., 1986, Are we on the verge of a mass extinction in tropical rainforests? *In* Dynamics of extinction. D.K.Elliott, ed., Wiley, New York, pp. 165-180.

Simon, J., and Kahn, H., eds., 1984, The resourceful Earth: a response to Global 2000. Basil Blackwell, Oxford, 600 p.

Stanley, S.M., 1979, Macroevolution. Pattern and process. W.H.Freeman, San Francisco, 332 p.

Stanley, S.M., 1984, Temperature and biotic crises in the marine realm. Geology, 12: 205-208.

Stanley, S.M., 1985, Extinction as a part of the natural evolutionary process. *In* Animal extinctions. R.J.Hoage, ed., Smithsonian Institution Press, Washington, DC, pp. 31-46.

Stanley, S.M., 1986, Anatomy of a regional mass extinction: Plio-Pleistocene decimation of the western Atlantic bivalve fauna. Palaios, 1: 17-36.

Thierstein, H., 1982, Terminal Cretaceous plankton extinctions: a critical assessment. *In* Geological implications of impacts of large asteroids and comets on the Earth. L.T.Silver and P.H. Schultz, eds., Geological Society of America Special Paper 190, pp. 385-400.

Vermiej, G.J., 1986, The biology of human-caused extinctions. *In* The preservation of species. B.G.Norton, ed., Princeton University Press, Princeton, NJ, pp. 28-49.

Vermeij, G.J., 1989, Saving the sea: what we know and what we need to know. Conservation Biology, 3(3): 240-241.

Vrba, E., 1980, Evolution, species, and fossils: how does life evolve? South African Journal of Science, 76: 61-84.

Ward, P.D., 1990, A review of Maastrichtian ammonite ranges. *In* Global catastrophes in Earth history. V.L.Sharpton and P.D.Ward, eds., Geological Society of America Special Paper 247, pp. 519-530.

Ward, P.D., 1994, The end of evolution. On mass extinctions and the preservation of biodiversity. Bantam Books, New York, 302 p.

Wilson, E.O., 1988, The current state of biodiversity. *In* Biodiversity. E.O.Wilson, ed., National Academy Press, Washington, DC, pp. 3-20.

Table 1. Generalized examples of selectivity during times of mass and "background" extinction (sensu Jablonski, 1986a).

	WHO GOES EXTINCT?		WHO SURVIVES?	
	BACKGROUND	MASS	BACKGROUND	MASS
MARINE	☐ "specialists" (1) ☐ geographically restricted taxa (3) ☐ species-poor taxa (3)	☐ suspension feeders (2,11) ☐ plankton/ nekton (4) ☐ tropical taxa (5,12) ☐ geographically restricted taxa (3,6,11) ☐ shallow water dwellers (11) ☐ species-poor genera (11)	☐ "generalists" (1) ☐ geographically widespread species (3) ☐ species-rich genera (3)	☐ deposit feeders (2) ☐ geographically widespread genera (3) ☐ estivators (10) ☐ "generalists" (11)
TERRESTRIAL	☐ "specialists" (1,7) ☐ geographically restricted taxa (8,9)	☐ large body size (8,9)	☐ "generalists" (1,7) ☐ geographically widespread taxa (8,9)	☐ small body size (8,9) ☐ freshwater dwellers (8,9)

References:

(1) Stanley (1979); (2) Sheehan and Hansen (1986); (3) Jablonski (1986a); (4) Thierstein (1982); (5) Stanley (1984, 1986); (6) Jablonski and Raup (1995); (7) Vrba (1980); (8) Clemens (1982); (9) Archibald (1996); (10) Kitchell et al. (1986); (11) Erwin (1993); (12) Kauffman and Erwin (1995).

CAMBRIAN TRILOBITE EXTINCTIONS, BIOMERES, AND STAGES

J. Stewart Hollingsworth
Geological Consultant
729 25 Road
Grand Junction, Colorado 81505

> "...a unique opportunity to study the greatest mystery in the history of our planet: extinction."
>
> Ian Malcolm in *The Lost World*

The earliest geologic period containing skeletonized life forms was the Cambrian Period, currently dated as 544 to 495 million years ago. In North American Cambrian rocks, six trilobite extinctions punctuate the evolutionary succession. Some of these extinctions are used to define series and stage boundaries (Series are subdivisions of a period while stages are subdivisions of a series). These mass extinctions were not as devastating as the better-known major extinctions in the Late Ordovician, Late Devonian, at the end of the Permian, in the Late Triassic and at the end of the Cretaceous.

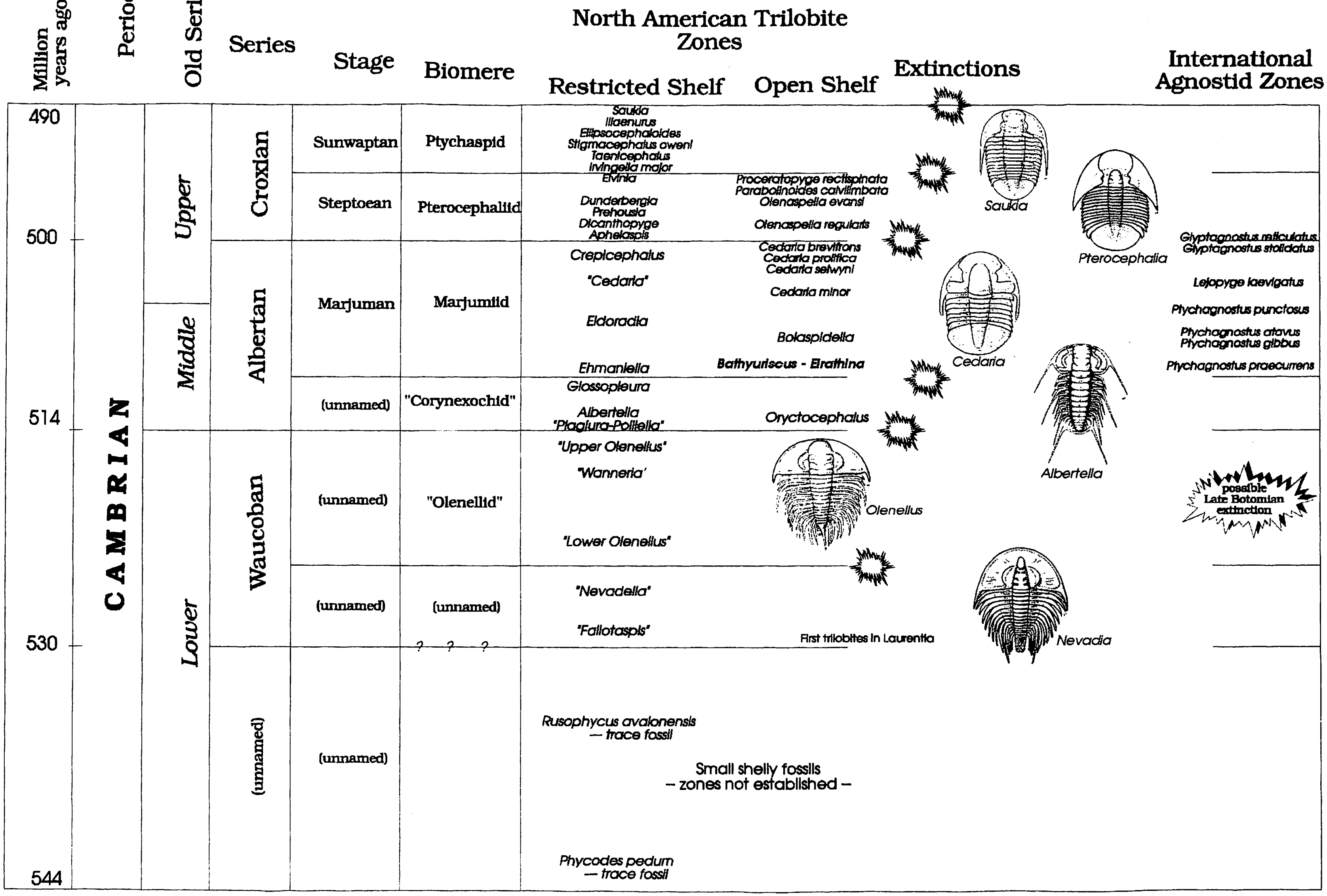
For the past few years I have worked with Dr. W. H. Fritz, Geological Survey of Canada, measuring stratigraphic sections and collecting fossils in western Nevada across the oldest Cambrian trilobite extinction.

Biomeres

For decades, Cambrian paleontologists had noted a repeating pattern of trilobite extinction and evolution. In 1965, A. R. (Pete) Palmer proposed the term "biomere" to represent an interval of trilobite evolution between two successive extinction events. A biomere starts with a few species in great abundance. These forms evolve rapidly to a variety of species. The rate of evolution eventually stabilizes until the next extinction event. Biomere boundaries qualify as mass extinctions since other groups show extinction as well: brachiopods, conodonts, and graptolites (Thomas, 1995).

The top three biomere boundaries are well defined at numerous localities in North America (Thomas, 1995; Westrop, 1990). Others are not well defined and their informal names are enclosed in quotation marks on Figure 1. The first extinction is the boundary that we are studying in Nevada.

Subdivisions of the Cambrian in North America



Million years ago	Period	Old Series	Series	Stage	Biomere	North American Trilobite Zones		Extinctions	International Agnostid Zones
						Restricted Shelf	Open Shelf		
490	**CAMBRIAN**	*Upper*	Croxian	Sunwaptan	Ptychaspid	*Saukia* *Illaenurus* *Ellipsocephaloides* *Stigmacephalus oweni* *Taenicephalus* *Irvingella major*			
				Steptoean	Pterocephaliid	*Elvinia* *Dunderbergia* *Prehousia* *Dicanthopyge* *Aphelaspis*	*Proceratopyge rectispinata* *Parabolinoides calvilimbata* *Olenaspella evansi* *Olenaspella regularis*		*Glyptagnostus reticulatus*
500		*Middle*	Albertan	Marjuman	Marjumiid	*Crepicephalus* *"Cedaria"* *Eldoradia* *Ehmaniella*	*Cedaria brevifrons* *Cedaria prolifica* *Cedaria selwyni* *Cedaria minor* *Bolaspidella* ***Bathyuriscus - Elrathina***		*Glyptagnostus stolidotus* *Lejopyge laevigatus* *Ptychagnostus punctosus* *Ptychagnostus atavus* *Ptychagnostus gibbus* *Ptychagnostus praecurrens*
				(unnamed)	"Corynexochid"	*Glossopleura* *Albertella* *"Plagiura-Poliella"*	*Oryctocephalus*		
514		*Lower*	Waucoban	(unnamed)	"Olenellid"	*"Upper Olenellus"* *"Wanneria'* *"Lower Olenellus"*			**possible Late Botomian extinction**
				(unnamed)	(unnamed)	*"Nevadella"* *"Fallotaspis"*	First trilobites in Laurentia		
530			(unnamed)	(unnamed)	? ? ?	*Rusophycus avalonensis* — *trace fossil* Small shelly fossils – zones not established – *Phycodes pedum* — *trace fossil*			
544									

Figure 1

Figure 1. Series, stage and biomere subdivisions of the Cambrian Period in North America. Named stages and biomeres are shown (Ludvigsen & Westrop, 1985) along with a sketch of a common trilobite for each biomere. Trilobite zones for restricted shelf, open shelf and the international agnostid zones are from many sources (Palmer, unpublished note; Pratt, 1992). Current information on isotopic ages is listed at the left.

Most of these biomere events are not clearly recognized on other continents. This may be due in part to the isolation of North America during the Cambrian (See Figure 2). The base of the Pterocephaliid Biomere can be correlated worldwide due to the presence of the international zone marker *Glyptagnostus reticulatus* near the base of the biomere (Palmer, 1962). The top of the Ptychaspid Biomere is a candidate for the Cambrian-Ordovician boundary but this is still being hotly debated. Some stage boundaries in the Ordovician have been described as biomere boundaries (Fortey, 1989).

These biomere extinctions are sharp. In many instances the last occurrence of the older trilobites is separated from specimens of the new group by centimeters or millimeters within a single bed. Microscopic examination reveals minute clayey discontinuity at the boundary in some cases (Palmer, 1984). More commonly, the extinction horizon is not marked by any change in lithology. In some cases, there is an unconformity (gap in the stratigraphic record) that is above the extinction event in the section and unrelated to it. One such major unconformity cuts out much of the Pterocephaliid Biomere across North America.

The biomere extinctions mainly effect the shallow continental shelf faunas. A new biomere begins with a "crisis" interval in which a few species from slowly evolving families in the outer continental margin invade the shelf to take over from the previous fauna. Some new species of older genera occur with the new groups. These are opportunists from the old order attempting to survive in this interval with the invaders. The invaders immediately achieve great abundance and rapidly evolve to occupy the many ecologic niches on the shelf producing a diverse fauna of short-lived species. Later, evolution becomes more orderly and species diversity continues to increase throughout the biomere. Finally, the next extinction event terminates the biomere.

These extinctions occur in 4 to 5 million year cycles, but two intervals of 10 million years or more are present without recognized biomere extinction events.

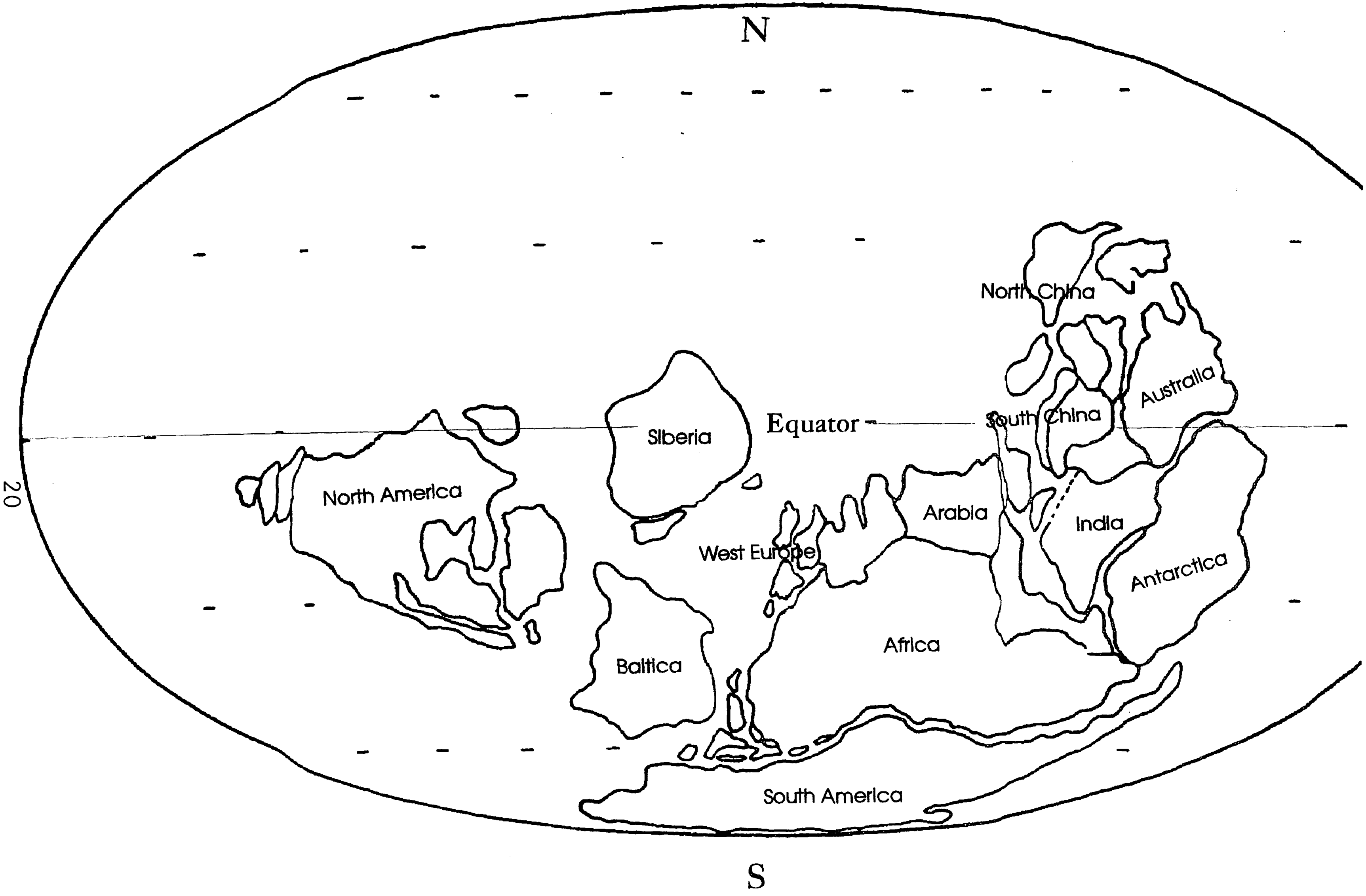


Figure 2. Position of the Laurentian (North American) continent with respect to the other continental masses at about 520 m.y. (Waucoban, Early Cambrian). Modified from Mansuy, et al, 1993.

What Caused These Cambrian Extinctions?

The causes for mass extinctions remain a matter of strong debate. An invasion of cold water caused by a rise in the oceanic thermocline has frequently been proposed. Alternatively, an influx of oxygen-depleted water from a stagnant, layered ocean may have been the primary cause. These causes likely involved a continent-wide (eustatic) rise in sea level.

Other workers blame eustatic sea level drop for the extinctions. As sea level falls, the existing shallow environment occupied by most trilobites is restricted to a narrow band between the shore and the steep continental margin. Dropping sea level, and rising thermocline, are commonly associated with global cooling and glaciation.

Under either the rising sea level (onlap) or falling (offlap) scenarios, the number of distinct favorable environmental niches may be severely reduced: by general flooding during onlap or by reducing the width of the continental shelf during offlap. The loss of favorable environments rather than loss of space, may have resulted in a general extinction (Westrop, 1990).

Extinction due to a bolide-impact has been investigated at the upper and lower boundaries of the Pterocephaliid Biomere. No trace element signatures of such an impact were found (Orth, et al, 1984). Other exotic causes such as virus infection or radiation bursts have been suggested, but remain to be investigated.

Some have argued that before an extinction event a successful fauna was progressively stressed. When the stresses reached a certain point, the fauna died out completely. In some cases better-adapted outer shelf forms began their invasion before the final stress point was reached. The maximum rise or fall of sea level need not have coincided with the final extinction event.

A Different Cambrian Extinction?

An entirely different extinction, marked by the death of 80% of the existent genera, has been suggested based on groups other than trilobites, principally the archaeocyathids (Signor, 1992). This event in the Lower Cambrian, termed the Botomian extinction, would rank with the other major extinctions (Zhuravlev & Wood, 1996). It seems to have occurred in two surges and is more clearly marked on other continents than on North America. However, some Cambrian workers suggest that this "extinction" is an artifact of our incomplete knowledge of fossil distribution in varying environments.

The Earliest Trilobite Extinction

For the past few years my work with W. H. Fritz in southwestern Nevada (Figure 3) has included measuring stratigraphic sections across the oldest known Cambrian extinction event. We are seeking a section providing the optimum record of this event and hope the section can serve as the North American stratotype for the boundary between two stages within the Waucoban Series.

In the Mackenzie Mountains of northwestern Canada, the first area studied by Fritz, the *Nevadella-Olenellus* boundary would fall within a quartzite unit that is barren except for the trace fossil *Skolithos*. Olenellids above the quartzite suggest that a substantial hiatus exists. This unconformity is present in most sections of the Lower Cambrian along western North America (Fritz, 1992). However in Esmeralda County, Nevada, and Inyo County, California, there appears to be continuous sedimentation across this interval (Nelson, 1978). In this area the boundary occurs in the Middle Member of the Poleta Formation and we have measured five sections across it. In three of these sections, we have collections defining the boundary spaced 0.5, 1.4, and 2.5 meters apart (Fritz, 1995, unpublished notes).

The *Nevadella-Olenellus* boundary. This boundary occurs within a 10-meter interval of shale with thin calcareous beds and lenses of mollusk-tube coquina. Some lower beds also have an abundance of inarticulate brachiopods. Thin sandstone beds with gutters also occur across the boundary. The beds below the extinction are olive green shale with a few bioclastic limestone lenses. Our tentative interpretation is that the sea was getting progressively shallower to a point well above the boundary interval.

A single species of *Nevadia* (Figure 4) is found below the boundary in the eastern area. In the western sections, however, thin bioclastic limestones have fragments of *Geraldinella?* (Fritz, 1995, unpublished notes). Within 15 meters of the boundary, two species of *Nevadella* become relatively common. The first trilobite above the boundary is *Olenellus?*, but this form is soon accompanied by a new genus. Above this is a diverse fauna including *Olenellus*, *Gabriellus*, *Laudonia*, *Mummaspis* and several new forms. Fritz is currently preparing a paper describing several of these new genera from a section in northern British Columbia.

Bradyfallotaspis, a genus that first appears about 250 meters below the boundary, survived the extinction event in the western sections where it occurs in the first few meters above the boundary. This interval should represent the crisis zone of biomere evolution, but there is little indication of the great trilobite abundance noted in crisis zones of later biomeres.

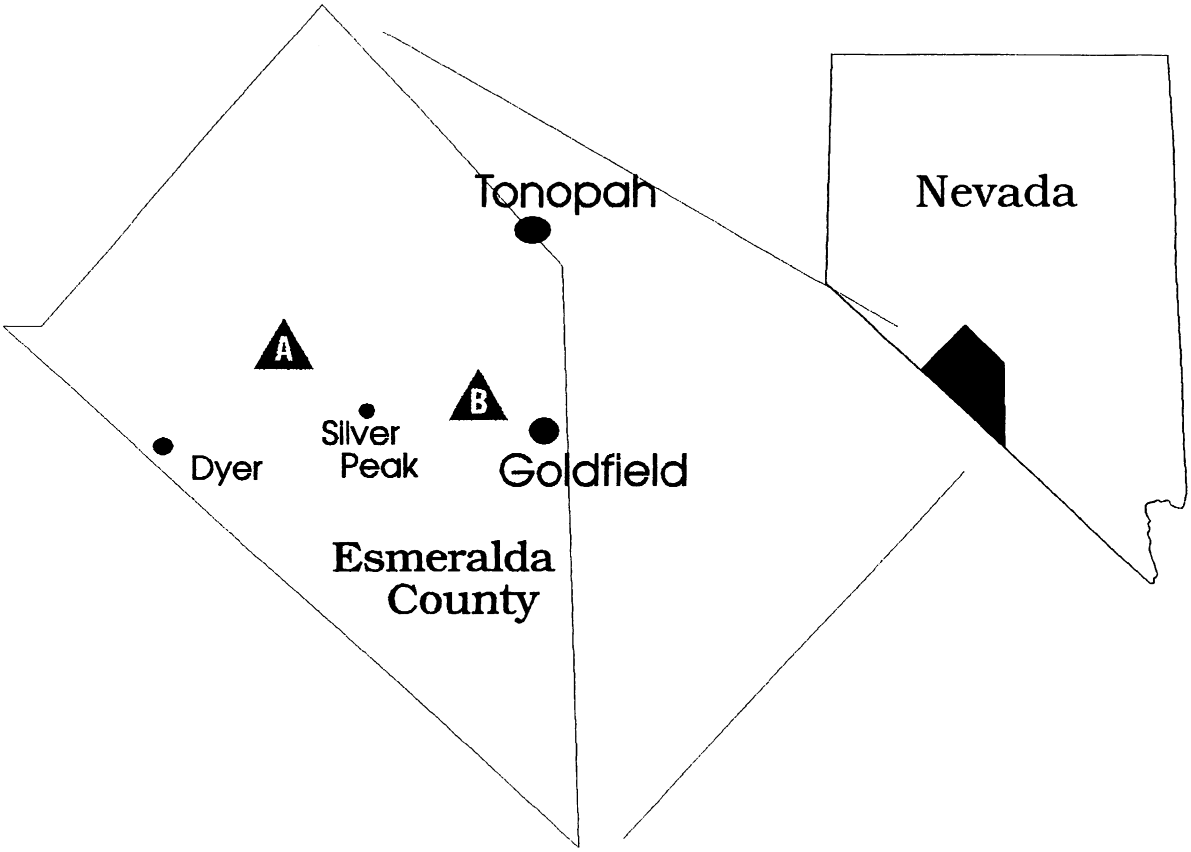


Figure 3. Map of Esmeralda County locating areas of Lower Cambrian stratigraphic sections under investigation.

The disappearance of the nevadiids with their narrow tapering glabella (nose, See Figure 4) and their replacement by the olenellids and laudoniids with their distinctly bulbous glabella (big-nose) clearly represents a typical Cambrian trilobite extinction.

The selection of the *Nevadella* extinction as the top of a stage is consistent with the later stage boundaries. The base of this stage, which is to be the base of Walcott's (1912) Waucoban Series is presently controversial. Some argue that the base should be placed at the arbitrary and non-extinction boundary between the "*Nevadella*" and "*Fallotaspis*" zones (Fritz, pers. comm.) since Walcott's oldest trilobites were from the "*Nevadella*" Zone. I suggest that Walcott's concept would have allowed us to include any older trilobites within the Waucoban. Thus the base of the Waucoban could be placed not at an extinction event, but at the first appearance of trilobites in North America.

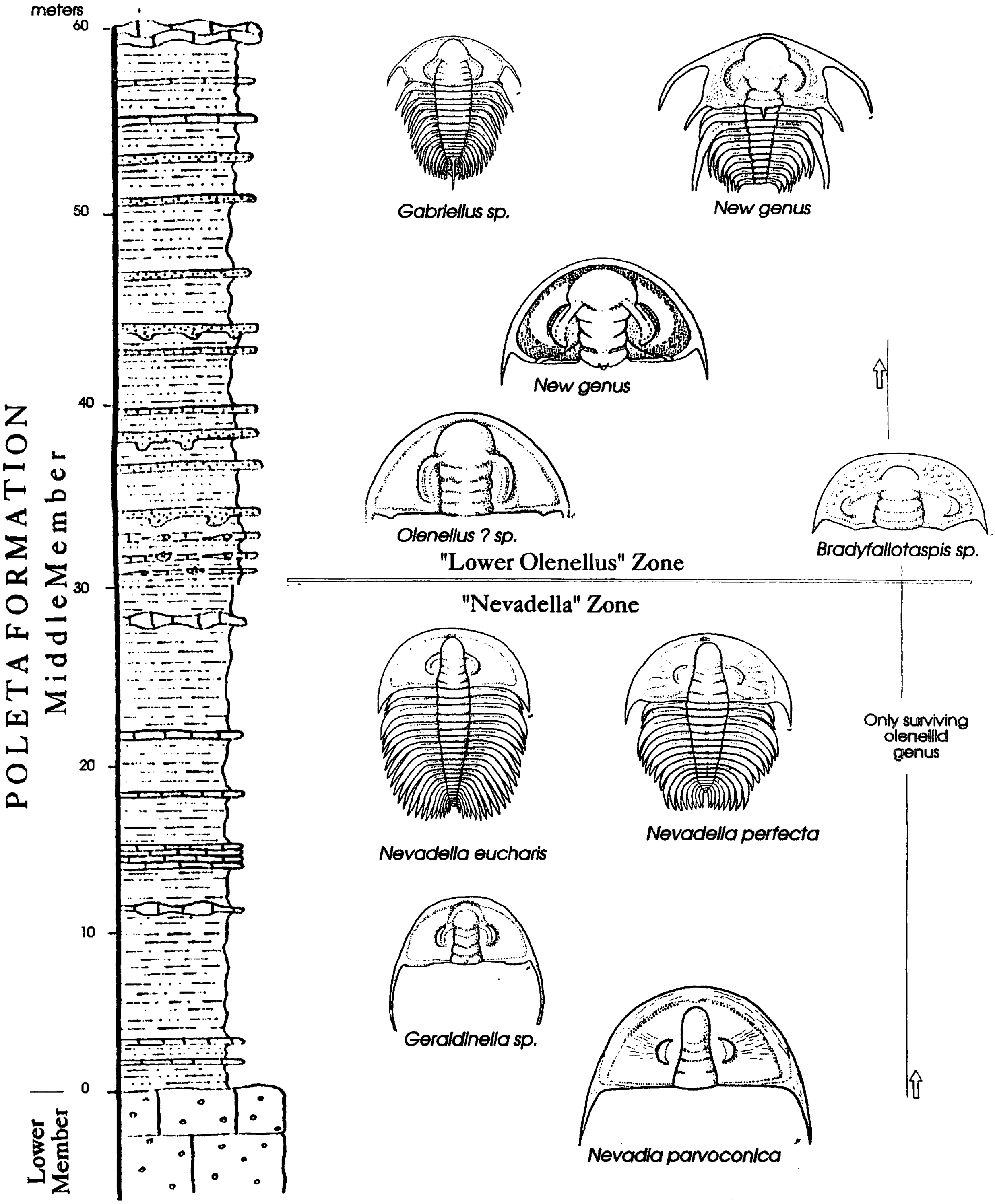


Figure 4. Stratigraphic section showing the lower part of the Middle Member of the Poleta Formation. This is a composite of three sections in the western area (Figure 3,A). The trilobite sketches show the variety of trilobites found above and below the Nevadella-Olenellus boundary. Several of these sketches are modified from Fritz (1992, and unpublished).

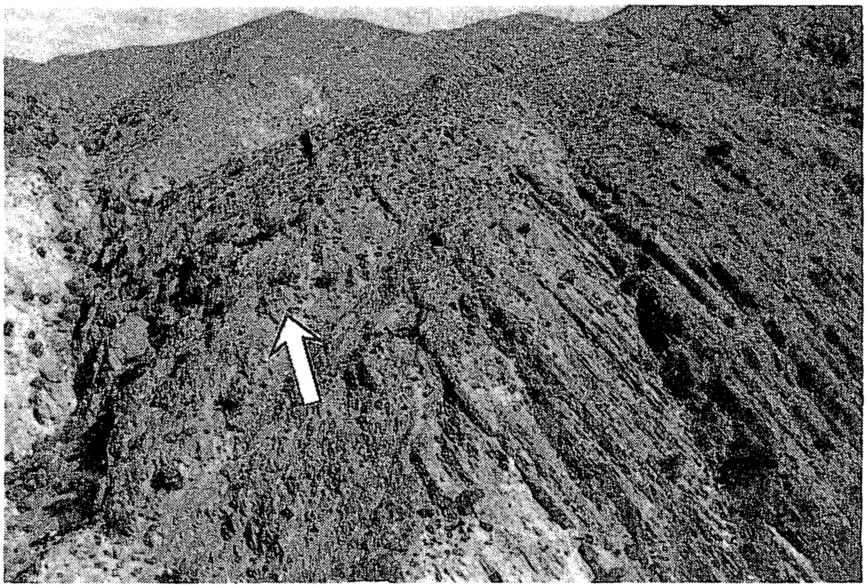


Figure 5. Middle Member of the Poleta Formation, the top of the Lower Member is at the left edge of the photograph. The *Nevadella-Olenellus* boundary is near arrow. Area "A", Esmeralda Co., Nevada.

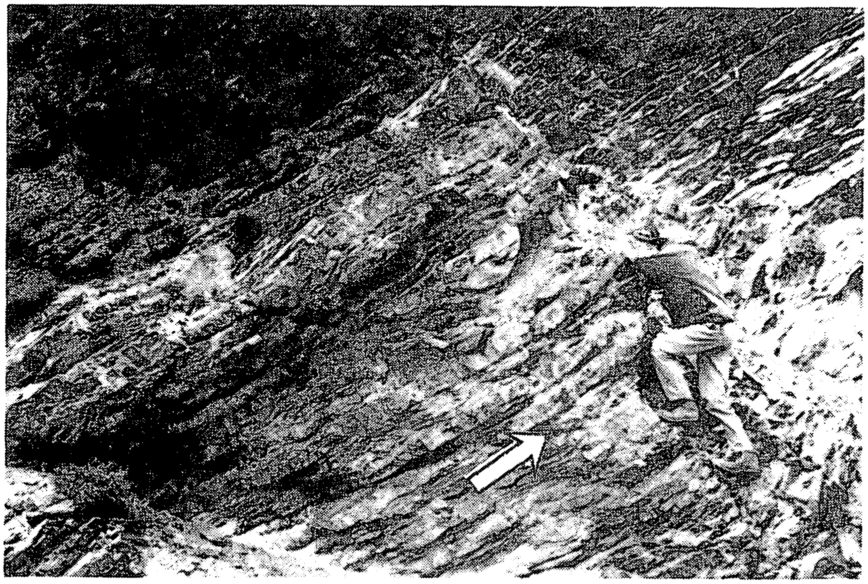


Figure 6. *Nevadella-Olenellus* boundary interval. "Gutter structures" at the base of sandstone layers visible near man's head. Same section as Fig. 5.

A Possible Biomere Interval. The trilobite zones below the *Nevadella* extinction might constitute another biomere interval, but lack an initial trilobite extinction because there were no earlier trilobites. Since the earliest stage of a biomere includes the abundant appearance of invading trilobites (Palmer, 1984), the base of this biomere might be drawn at the first abundant occurrence of the fallotaspids. The finding of isolated older trilobites should be accepted as early tentative invasions of a newly evolved form.

The 600 meters of shale and limestone below the *Nevadella* extinction contains a diverse, rapidly evolving fauna of occasionally abundant trilobites. Beginning near the base of the Montenegro Shale Member of the Campito Formation, five species of *Fallotaspis* and *Parafallotaspis* appear suddenly. After a barren interval, *Paranevadella* and "*Daguinaspis*" are found (Nelson, 1978). These are followed by a "pre-*Nevadia*" and another new genus, then by *Palmettaspis*, *Nevadia* and *Esmeraldina* which appear in abundance (Fritz, 1995). In the Lower Member of the Poleta Formation, *Holmiella*, and a new genus resembling *Holmia* appear with *Nevadia*, *Cirquella* and *Bradyfallotaspis*. Ptychoparioids appear near the archaeocyathid mounds of the Lower Poleta. No trilobites have been found in the thick carbonate at the top of the Lower Member of the Poleta.

Other fossils found in this interval include abundant trace fossils, a possible worm *Onuphionella* (?) (Signor & McMenamin, 1988), scarce brachiopods, abundant hyolithids, a variety of small shelly fossils including *Stenothecoides*, and 27 species of archaeocyathids (McKee and Gangloff, 1969). Echinoderm plates are sparse and entire helicoplacoids have been found at the base of the Middle Poleta (Durham, 1993).

Are Cambrian extinctions the product of events that are exclusive to the Cambrian (and perhaps early Ordovician), or simply zonal boundaries? This remains a matter of some contention. Much additional work is needed to define the distribution of Cambrian fossils, especially in the lower part of the Cambrian.

Acknowledgements.

I have freely used many ideas discussed with W. H. Fritz in the field. The conclusions presented herein are, however, my own. The manuscript has been graciously read and critiqued by Pete Palmer and Bill Fritz.

References.

Durham, J. W., 1993, Observations on the Early Cambrian helicoplacoid echinoderms: Journal of Paleontology 67(4): 590-604.

Fortey, R. A., 1989, There are extinctions and extinctions: examples from the Lower Paleozoic: Philosophical Transactions of the Royal Society of London Bulletin 325: p. 327-355.

Fritz, W. H., 1972, Lower Cambrian trilobites from the Sekwi Formation type section, Mackenzie Mountains, northwest Canada: Geological Survey of Canada Bulletin 212: 90 p.

Fritz, W. H., 1992, Walcott's Lower Cambrian olenellid trilobite collection 61K, Mount Robson area, Canadian Rocky Mountains: Geological Survey of Canada, Bulletin 432, 65 p, 17 pls.

Fritz, W. H., 1995, *Esmeraldina rowei* and associated Lower Cambrian trilobites (1f fauna) at the base of Walcott's Waucoban series, southern Great Basin, U.S.A.: Journal of Paleontology 69(4): 708-722.

Ludvigsen, R. & Westrop, S. R., 1985, Three new Upper Cambrian stages in North America: Geology 13:139-143.

Mansy, J.-L., Debrenne, F. and Zhurvlev, A. Yu., 1993, Calcaires à archéocyathes du cambrien inférieur du Nord de la Colombie britannique (Canada). Implications paléogéographiques et précisions sur l'extension du continent Américano-Koryakien. [Lower Cambrian Archaeocyath limestones of Northern British Columbia (Canada). Paleogeographic implications and precessions on the Americano-Koryakian continent extension]: Geobios 26(6): 643-683.

McKee, E. H. and Gangloff, R. A., 1969, Stratigraphic distribution of archaeocyathids in the Silver Peak Range and the White and Inyo Mountains, western Nevada and eastern California: Journal of Paleontology, v. 43, p. 716-726.

Nelson, C. A., 1978, Late Precambrian-Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary: Geological Magazine 115(2): 121-126.

Orth, C. J., Knight, J. D., Gilmore, L. R. and Palmer, A. R., 1984, A search for iridium abundance anomalies at two Late Cambrian biomere boundaries in western Utah: Science, 223: 163-165.

Palmer, A. R., 1962, *Glyptagnostus* and associated trilobites in the United States: U.S. Geological Survey Professional Paper 174-F: F1-F49.

Palmer, A. R., 1965, Biomere - A new kind of biostratigraphic unit: Journal of Paleontology 39: 149-153.

Palmer, A. R., 1984, The biomere problem: Evolution of an idea: Journal of Paleontology 58: 599-611.

Pratt, B. R., 1992, Trilobites of the Marjuman and Steptoean stages (Upper Cambrian), Rabbitkettle Formation, southern Mackenzie Mountains, northwest Canada: Palaeontographica Canadiana, 8: 179 p.

Signor, P. W., 1992, Taxonomic diversity and faunal turnover in the Early Cambrian: Did the most severe mass extinction of the Phanerozoic occur in the Botomian Stage?: North American Paleontological Convention, 5th, Abstracts with Programs, p. 272.

Signor, P. W. and McMenanin, M. A. S., 1988, The Early Cambrian worm tube Onuphionella from California and Nevada: Journal of Paleontology, 62(2): 233-241.

Thomas, R. C., 1995, Cambrian mass extinction ('Biomere') boundaries: a summary of thirty years of research. in Mogk, D. W., ed., Field Guide to Geologic Excursions in southwest Montana: Northwest Geology, 24: 67-75.

Walcott, C. D., 1912, Cambrian Geology and Paleontology, II: Group terms for the Lower and Upper Cambrian series of formations, No. 10.: Smithsonian Miscellaneous Collections 57: 305-307.

Westrop, Stephen R., 1990, Mass extinction in the Cambrian Trilobite Faunas of North America. in Arthropod Paleobiology: the Paleontological Society, Short Courses in Paleontology 3:99-115.

Zhuravlev, Andrey Yu. and Wood, Rachel A., 1996, Anoxia as the cause of the mid-Early Cambrian (Botomian) extinction event, Geology 24(4): 311-314.

CONULARIIDA

Robert L. Guenther
149 East Main Street
Shelby, OH 44875

For the study of conulariids, the genus Conularia may be chosen as a representative type.

Shells elongate - pyramidal, with the sides equal and diverging from the apex at an angle of about sixteen degrees; lateral surfaces nearly flat, and the mesial furrow varies with different species of the conularids. Each of the four angles a little rounded and provided with a shallow, moderately distinct longitudinal furrow. The surface has numerous extremely small, closely crowded transverse striae which varies with different species on all parts of the skin. These species are remarkable for the extreme fineness and closely crowded uniform character of the transverse striae on all parts of the surface, giving even fragments of the skin a very distinct pattern that is recognizable at a glance, for no other creature that I know of has this distinct pattern.

Fossils that resemble Conularia have been found in late Precambrian rocks in North America, and in South Africa. The conularids I am acquainted with, are the varieties found in the periods of rocks that are exposed in Ohio. The chart below gives some of these conularids, and the periods of rock formations in which you may be able to find them.

Ordovician - Conularia formosa - Maysville and Richmond Formations, Cincinnati, Ohio

Silurian - Conularia niagarensis - Brassfield Formation, Piquoa, Ohio

Devonian - Conularia undulata - Conrad
Conularia africana - Icala Cal-Nod beds, Bolivia, South America

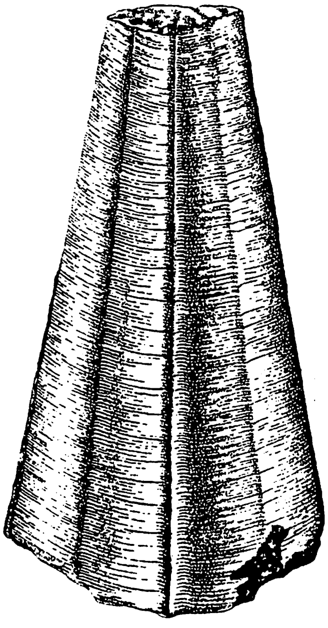
Mississippianian - Conularia micronema - Cuyahoga Formation, S. Ashland County Ohio.
Paraconularia newberryi Cuyahoga Formation, S. Ashland County, Ohio

Pennsylvanian - Conularia crustula- Wyandotte Ls. , Kansas City, Kansas

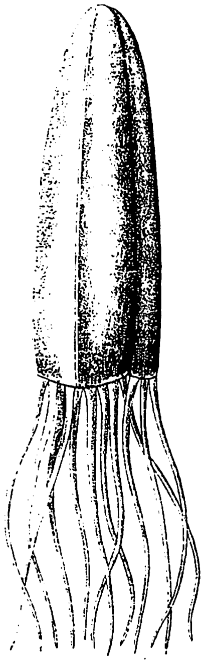
Permian - Becoming quite rare, but still available.

SHELLS OF TWO CONULARIANS.
RESTORATIONS SHOW ONE FLOATING AND ONE ATTACHED

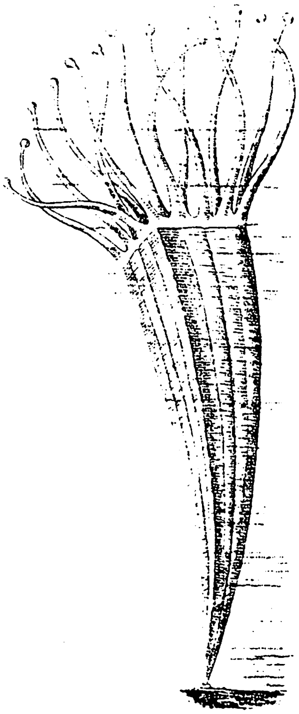
Paraconularia
Mississippian



Conularia undulata Conrad
Middle Devonian

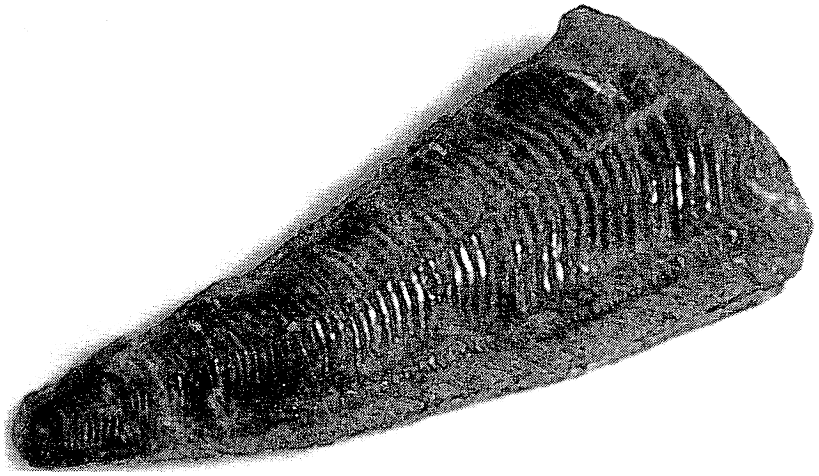


Exoconularia in the
free-swimming state.
Ordovician



Archaeoconuiaria, attached.
Ordovician and Silurian

This is a Conularia newberryi fossil that was in a round horizontal concretion



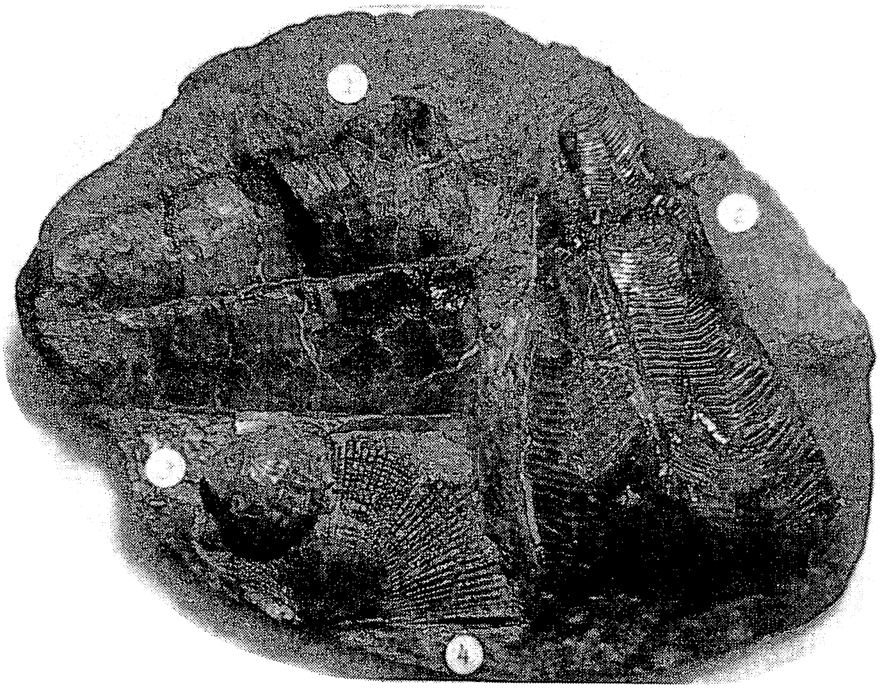
The Conularids became extinct along with approximately 90% of all living species, when they were engulfed in the great catastrophe of the Permo-Triassic extinction about 250 million years ago. There are many scientific theories about how such an event, or what combination of natures furies from meteorites impacts, underseas eruptions, poison gases from volcanoes, tidal waves, or hypercanes could cause such a world-wide destruction, that drastically changed all resulting forms of life on earth. The answer still eludes the ever curious minds of the Homo sapian races that profited in the evolution, along with many new species that didn't even exist before that world changing time.

This beautiful fossil of a marine animal has been bounced from one phylum to another, because the morphology was misunderstood, or misinterpreted by early scientists that tried to pinhole them into phylums of worms, mollusks, or coelenterates, so most of the fossil books printed before 1937 gives erroneous information about the conularids.

Finally somebody wised up enough to put the conularids in a new phylum of their own, realizing that they are an extinct branch of the jellyfish family, and with a new phylum, "CONULARIIDA" they can now rest in peace. This four sided elongated pyramidal marine animal in the juvenile stage, was fastened to the bottom of the ocean, or to some other surface by a slender flexible stalk at the apex end, and floated in a vertical position where it could feed on whatever the water currents supplied in the way of food. The tentacles extended upward from the edge of the body while fastened to the stalk and when it broke loose from the stalk, it reversed the body position to have the apex at the top with the tentacles hanging down. In this vertical position it could float freely with the waters currents carrying it along, or by flexing its sides could swim probably much like the modern jellyfish.

Conularids have been found world-wide in rock formations of all of the continents with the exception of Antarctica, and it is a possibility that in time, one may make an appearance there. Being a gregarious marine animal, if you find one, there will probably be more in the vicinity, so check the location carefully and if there are other concretions, carefully tap with your pick or hammer along the edges of the concretions to see if a conularid is hiding inside. Of the conularids that I have collected, probably over 95% of them have been located inside of concretions. The few that I have found directly in the shales are usually weathered, and are not in prime condition.

This is a "One Of A Kind" concretion that has quite an unusual group of Mississippian Period fossils from the Waverly group of the Guyahoga Formations in south Ashland County Ohio. When I entered it in 'self collected' single competition at the Central Ohio Gem, Mineral & Fossil show in Columbus, Ohio, it won the First Place Blue Ribbon for 1995. Then the following year, I entered it in the 'self collected' single fossil competition at the Cincinnati Gem, Mineral & Fossil Show, and again won the First Place Blue Ribbon for 1996, so when it comes to the collecting of fossils, - I must be dragging home the right kind of fossils!!!

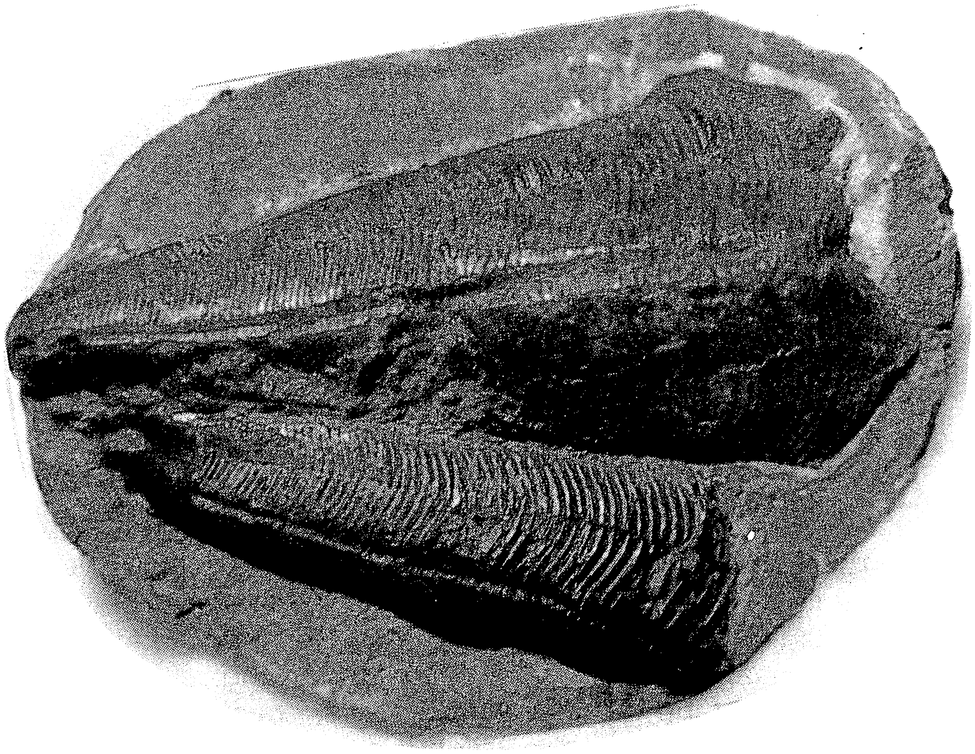


No.1 <u>Conularia</u> <u>micronema</u> No. 2 <u>Conularia</u> <u>newberryi</u> No. 3 <u>Productus</u> brachiopod No. 4 <u>Aviculopecten</u> pelecypod

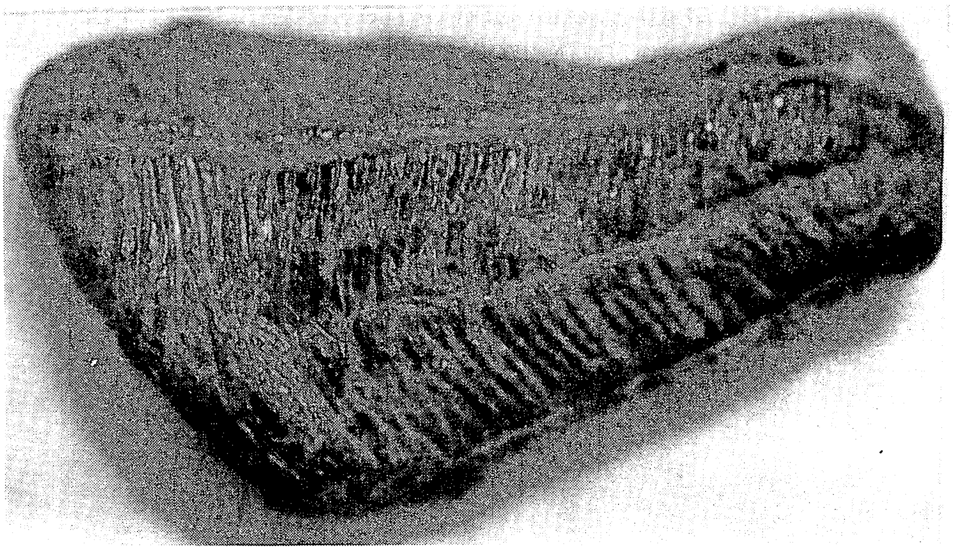
Usually by looking at the concretions, you can tell by the shape, thickness, and the composition of the concretion, whether there will be a possibliiyty of finding one of the unique fossil Conularids hiding inside. The single specimens usually have an elongated triangular shape that is usually thicker than the other concretions in the same formations. Most of the <u>Conularia</u> <u>micronema</u> specimens are flattened in the concretions that are in the horizontal position in the shale formation, and when they are split open, two sides of the fossilized animal are exposed.

The concretions that have the <u>Counlaria</u> <u>newberryi</u> inside seem to be of a more robust nature, producing a more three dimensional shape of the original animal before it became a fossil, and resulting in a concretion that measures about the same in thickness, front to back as it does side to side, or in other words, it can be one extra fat concretion. The first one of these Conularia newberryi fossils, was about seven inches in length and was the nicest one that I ever found. It is proudly displayed in the Fryxell Geology Museum at Augustana College located in Rock Island, Illinois. If you ever get close, stop in, it dosen't cost anything to look!!!

The fact that the conularids are gregarious animals brings up an interesting situation, that when a concretion shows up of an unusual shape or size, a little time should be taken on how it should be opened, for it might have more than one conularid or other species of marine animals enclosed. I have found up to five Conularia micronema well preserved fossils in a concretion that was over one foot in diameter and about five inches in thickness. Another appeared when an extra large concretion produced 31 Platyceras lodiense snails. Sometimes there is more than one conularid in these concretions, and while they can be in pairs that are of the same species, there can also be ones that are of different species.

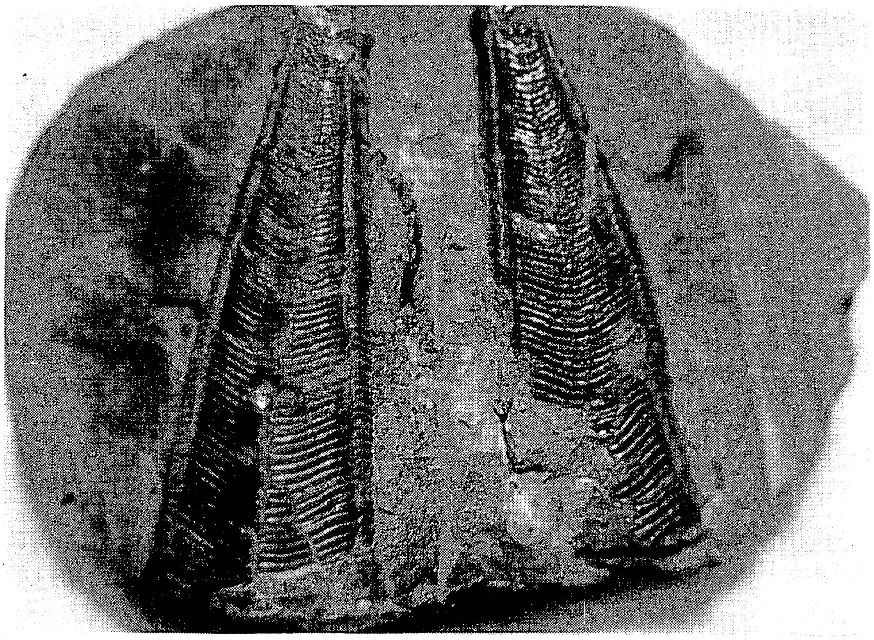


The Conularid pictured below is from one of the Cuyahoga Formations from the Hayesville, Ohio location, and with over fifteen years of hunting fossils in that area, without seeing even a fragment of skin I was quite suprised when my sharp eye-sight spotted a quarter inch triangular design about five inches back in the layer of shale, that could be nothing but the pattern of a conularid. By carefully working the shale that had preserved it for millions of years, from around it, more and more of the conularids appeared and I soon had a new specimen in my hand that was a three dimentional Conularia newberryi fossil, and it had been in the verticle position in the shale, with the apex at the top.



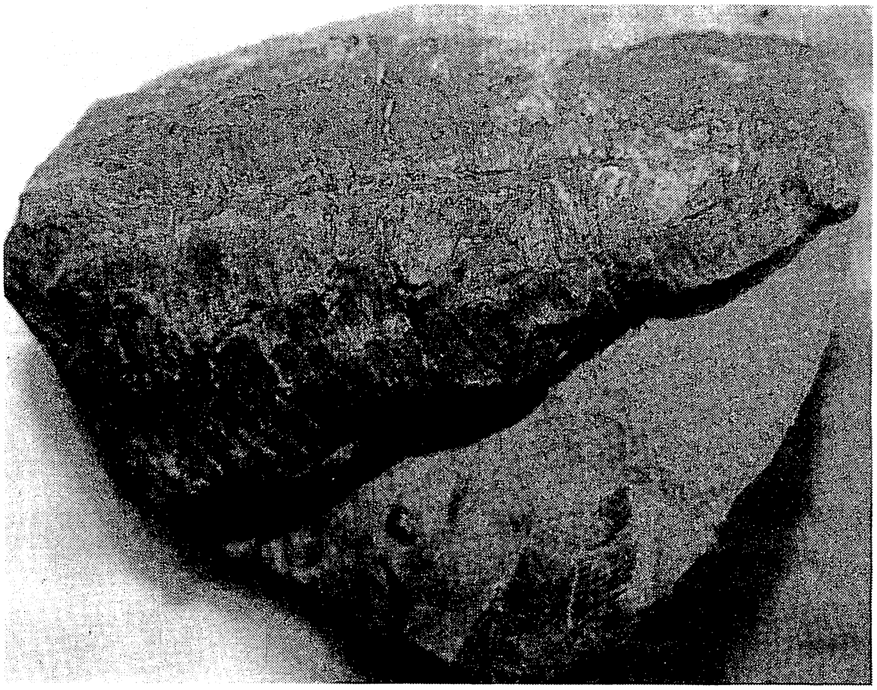
Below is a Conularia africana from the Devonian Period that was found in the Calc - nod bed of the Icala Formation in Belen, Boliva, South America, and is part way out of a concretion.

This unusual pair of Paraconularia newberryi shows another fossil that is quite common in these fossils bearing concretions, and which I believe is a piece of a conularid tentacle. This one is between the two conularids. Some of these tentacle pieces can be as long as five inches, and are of the same material and color as the conularid skins. When this concretion split vertically through the center, the left conularid was only partically showing, and while trying to clear part of the concretion away to see the whole fossil, the tentacle and the other conularid came into view, but this was only half of the concretion. The other half showed nothing but the partial impression of the left conularid. This is where the dedicated optimism of an old fossil picker might make a difference. By carefully flaking off the facing other piece of the concretion, there appeared another conularid of the same size, and all three of them was in a vertical position in a circular horizontal concretion with the apexes at the top.



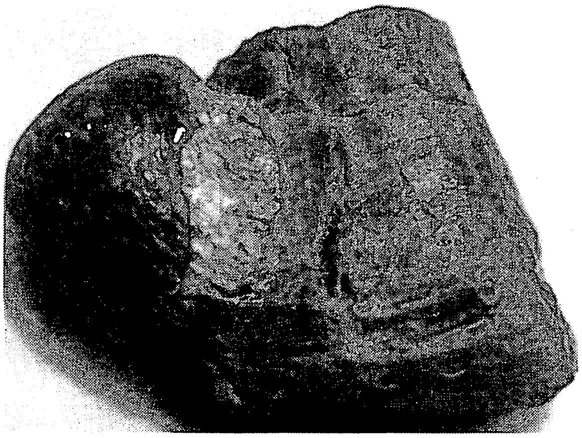
The small Conularia newberryi below is one of the flattened conularids found in a flattened
concretions in horizontal position.

This picture is of a pair of conularids, the top one which is a Conularia micronema, is completely exposed so it can be lifted free of the concretion that shows a partially exposed Conularia newberryi buried underneath the top conularid.



This picture also shows a pair of Conularia micronema, with one completely exposed, and another that is partially exposed, buried under the top one.

This unusual fossil was quite a surprise when I picked it up and washed the mud off of it, that it was a two-in-one type of fossil. The way the Buxtonia scabricula brachiopod was joined to the side of the three dimentional Conularia micronem species of conularid suggests that this relationship was a lifetime adventure, because both of these animals were in the adult stage of life when they were preserved. How long they had been that way - your guess is as good as mine???



REFERENCES:

Geological Survey of Ohio, vol. II , Geology and Palaeontology, Part II - Palaeontology ,1875.

Bulletin 54, Ohio Fossils, by Aurele La Rocque and Mildred Fisher Marple, Division of Geological Survey-- Fourth Printing, 1961, Columbus, Ohio.

The Fossil Book - A record of Prehistoric Life, Carroll Lane Fenton and Mildred Adams Fenton

Elementary Guide to the Fossil and Strata of the Ordovician in the vicinity of Cincinnati, Ohio.
Revised by:
Kenneth E. Caster
Elizabeth A. Dalve
John K. Pope
The University of Cincinnati

THE BRYOZOAN EXTINCTION RECORD

Alan S. Horowitz
Department of Geological Sciences
Indiana University
Bloomington, Indiana 47405
and
Joseph F. Pachut
Department of Geology
Indiana University-Purdue University at Indianapolis
723 West Michigan Street
Indianapolis, Indiana 46202

ABSTRACT.--A review of bryozoan Phanerozoic species diversity yields a pattern comparable to a previous bryozoan compilation as well as to the family diversity of all marine organisms. The rate of mass extinction events can not be evaluated for bryozoan data compiled to geologic stage and based on current radiometric time-scales. Bryozoans exhibit reduced diversity following the end of the Ordovician and Cretaceous as well as the end of the Givetian (Devonian), Artinskian and Kazanian (Permian) stages. Other apparent reductions may be artifacts of the short lengths of some stages. Bryozoans generally are more abundant and diverse at times of widespread shallow continental seas. The causes of major extinction events is probably complex as no single cause appears to account for all events.

This preliminary report is a part of a longterm project to compile the taxonomic diversity, extinctions, and originations of fossil bryozoans for several taxonomic categories (from highest to lowest: order, family, genus, species). This summary is based principally on species.

Compilations of the names of living and fossil animals and plants have a long history, but modern usage for animals is formally recognized as beginning with publication in 1758 of the 10th edition of Systema Naturae by the Swedish biologist Karl von Linne, usually cited by his Latin name Carolus Linnaeus.

Compilations of fossil names began in the 19th century and by 1860 sufficient summaries were available for John Phillips to publish in 1860 a generalized graph (see reproduction in Rudwick, 1976, p. 240, fig. 5.2) showing the general diversity of life through the Phanerozoic, commonly regarded as extending from the beginning of the Cambrian period to the Recent. The end- Permian and end-Cretaceous extinctions are clearly indicated in Phillips graph. In the 136 succeeding years, we have added finer and finer detail but no major change to the general pattern of Phillips' figure. Phillips created the terms Mesozoic (middle life) and Cenozoic (recent life) as extensions of Sedgwick and Murchison's term Paleozoic (old life) and these terms were the divisions of the geologic timescale in Phillips' graph. The most widely cited modern version of fossil diversity through time was compiled by Sepkoski (Figure 1) and is based on the diversity of families of marine animals.

Our compilations are based on examination of previous compilations, the primary taxonomic literature, and on the yearly list of new names, reassignments, and redescriptions given in the Zoological Record. We have previously discussed procedures for the compiling and for the rejection of inappropriate names (Horowitz and Pachut, 1993).

Unequivocal Cambrian bryozoans are unknown, and bryozoans are apparently the only major skeletonized phylum to have an Ordovician origin. We have used unpublished Ordovician and Silurian species compilations by Tuckey (see references in Anstey & Pachut, 1995), published Devonian compilations (Horowitz & Pachut, 1993; Horowitz, Pachut & Anstey, 1995), our unpublished Carboniferous, Permian, Triassic, Jurassic, and Cretaceous compilations, and a Cenozoic compilation (Horowitz & Pachut, 1996) to illustrate the Phanerozoic diversity of bryozoan species. Additionally, we also have found useful the compilation of Sherborn (1902; 1922-1933) for the years 1758-1850, Nickles & Bassler (1900) for 19th century North American bryozoan names, McKinney (1969, 1974) for Paleozoic trepostomatous bryozoans, and Bassler (1915) for early 20th century Ordovician and Silurian North American names.

Our lists of fossil and recent bryozoans currently contain nearly 20,000 species names. Nevertheless, our compilations are subject to errors of omission and commission and are not exhaustive, but are an attempt to convey the present state of knowledge of bryozoan diversity and conclusions derived from this diversity. New names continue to be created as new materials are discovered so that compilations of fossil and recent biologic names are progress reports. We have assumed the sampling to date has been sufficiently broad that the major patterns will not be changed by the addition of new bryozoan names. Sepkoski et al. (1981) and Sepkoski (1993) have affirmed the pattern present in a compilation of diversity encompassing many animal groups found in the fossil record.

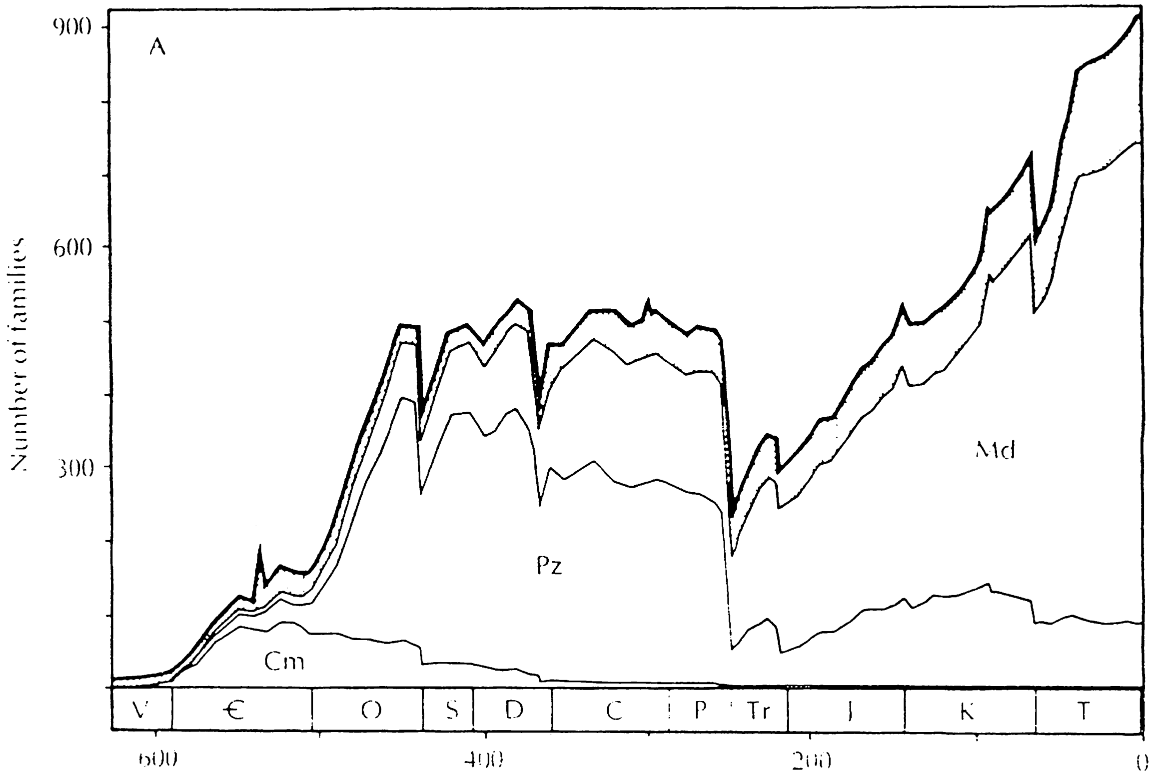


Figure 1. Phanerozoic diversity patterns for marine families (after Sepkoski, 1984). Three fields (Cm = Cambrian, Pz = Paleozoic, & Md = Modern) display chaning diversities of evolutionary faunas. Different bryozoan groups are contributors to the Paleozoic versus the Modern evolutionary faunas.

Table 1. Periods and stages with durations in million of years (MY). Data principally from Gradstein and Ogg (1996).

System/Epoch/Stage	MY
Quaternary	1.8
Holocene	.01
Pleistocene	1.8
Neogene	22.0
Pliocene	3.5
Piacenzian	1.8
Zanclean	1.7
Miocene	18.5
Messinian	1.8
Tortonian	4.1
Serravallian	3.6
Langhian	1.6
Burdigalian	4.1
Aquitanian	3.3
Paleogene	41.5
Oligocene	9.9
Chattian	4.7
Rupelian	5.2
Eocene	21.1
Priabonian	3.3
Bartonian	4.3
Lutetian	7.7
Ypresian	5.8
Paleocene	10.2
Thanetian	3.1
Selandian	3.0
Danian	4.0
Cretaceous	76.9
Maastrichtian	6.3
Campanian	12.2
Santonian	2.3
Coniacian	3.2
Turonian	4.5
Cenomanian	5.4
Albian	13.3
Aptian	8.8
Barrenmian	6.0
Hauterivian	5.0
Valanginian	4.5
Berriasian	5.4
Jurassic	63.8
Tithonian	8.8
Kimmeridgian	3.4
Oxfordian	5.3
Callovian	5.0
Bathonian	4.8
Bajocian	7.3
Aalenian	3.6
Toarcian	9.5
Pliensbachian	5.7
Sinemurian	6.6
Hettangian	3.8
Triassic	44.5
Rhaetian	3.9
Norian	11.1
Carnian	6.7
Ladinian	6.9
Anisian	7.4
Scythian	8.5
Permian	41.8
Tatarian	3.9
Dorashamian	1.9
Djulfian	2.0
Guadalupian	3.9
Kazanian	2.0
Ufimian	1.9
Leonardian	13.0
Kungurian	4.0
Artinskian	9.0
Wolfcampian	21.0
Sakmarian	13.0
Asselian	8.0
Carboniferous	64.0
Gzhelian	6.5
Kasimovian	6.5
Moscovian	8.0
Bashkirian	12.0
Serpukhovian	4.0
Visean	15.0
Tournaisian	12.0

Table 1 - continued

System/Stage	MY		MY
Devonian			
Famennian	10.0	Ordovician	
Frasnian	6.0	Ashgill	6.0
Givetian	10.0	Caradoc	9.0
Eifelian	11.0	Llandeilo	6.0
Emsian	9.0	Llanvirn	6.0
Pragian	12.0	Arenig	15.0
Lochkovian	5.0	Tremadoc	10.0
Silurian			
Pridoli	2.0		
Ludlow	4.0		
Wenlock	5.0		
Llandovery	15.0		

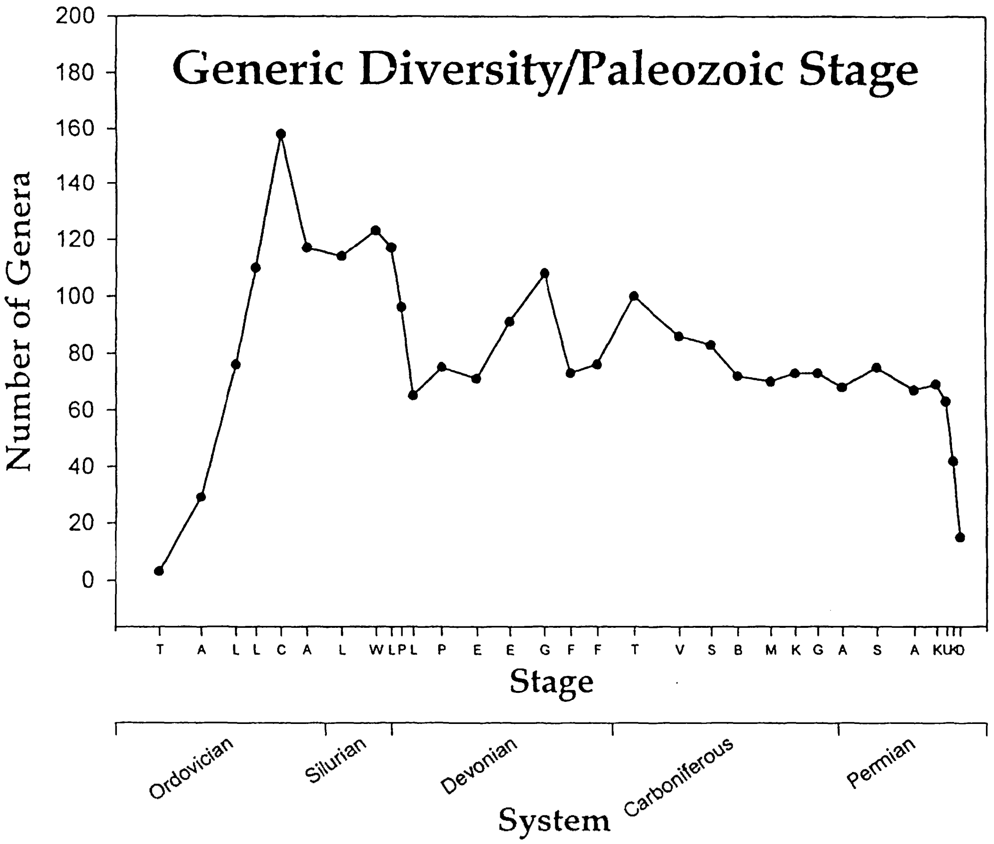


Figure 2. Phanerozoic diversity of bryozoans for geologic systems. Raup's 1976 estimates compared with current data based on a somewhat broader search and an additional quarter century of published studies.

Our summary of higher bryozoan categories is not complete, but the diversity of genera, families, and orders of Paleozoic bryozoans has been published by Anstey and Pachut (1995). Bryozoan monographs published in the former Soviet Union also commonly contain graphs of diversity at different taxonomic levels. Higher taxononic levels or categories (genus, family, order) have longer ranges than individual species because they are more lifely to be composed of the ranges of many species. Consequently, the absolute size of diversity peaks is reduced as one goes to higher taxonomic levels or categories. Additionally, the hierarchial arrangement of species within genera, genera within families, and families into orders reduces the absolute number of categories within stages.

The sedimentary record contains examples of many types of events ranging from daily tidal cycles to hundred million year cycles of icehouse to greenhouse conditions. Precise dating of events or individual short-term cycles in years before the present is not always possible although the lengths of some cycles can be inferred from a knowledge of astronomical cycles. Dating of ancient cycles requires that cycles contain both fossils and radiometrically datable materials. The integration of the results of studies of fossils and radiometric ages has been slow but steady, but the resolution is still in millions of years for much of the Paleozoic and Mesozoic and perhaps tens of thousands of years in the late Cenozoic. Consequently, resolution may vary by several orders of magnitude over the length of Phanerozoic time. The smallest unit of geologic time in our survey is the stage. Stages are of unequal time intervals and may vary by a factor of 7 or more (Table 1). We have used a radiometrically calibrated timescale based on the recent timescale of Gradstein and Ogg (1996) for the bryozoan graphs. This timescale has longer stage lengths for Devonian stages than those given by Fordham (1993), which Horowitz & Pachut (1995) used. Not all bryozoan species ranges have been reported to stage so that species reported only to period do not appear in the graphs plotted to stage.

The stages used in this study (Table 1) are generally those in Gradstein and Ogg (1996). International stage nomenclature is still undergoing revision and how some previous bryozoan studies will fit into the newer schemes is not clear. A recently recognized late Pliocene Gelasian stage is included in the Piazencian and the Selandian is included in the Thanetian in our compilation. The early Triassic Griesbachian-Spathian stages are combined as the Scythian stage because the small number of bryozoan reports from this interval have not been consistently assigned to these smaller stage intervals. Permian divisions and stages are currently undergoing revision and we have adopted most of the stages and their relations as designated in Erwin (1993).

Major extinction events are recognized in several ways, for example, by major changes in the composition of floras or faunas or by marked drops in total fossil diversity. Both of these changes are apparent in Figure 1 in the late Permian (end of the Paleozoic). In the case of bryozoans (Figure 2), extinction events are marked by drops in diversity at the end of the Ordovician and the Permian. The length of periods precludes determining the rate of the decreases. At the scale of periods, the widely discussed extinction event at the end of the Cretaceous does not appear in the bryozoan data. On the other hand, the pattern of bryozoan diversity (Figure 2) is consistent with the pattern for all marine (mostly invertebrate) animals (Figure 1).

Our compilation (Figure 2) also shows the changes in bryozoan diversity published by Raup (1976). Raup's work was based on a sampling of names cited in the Zoological Record between 1900 and 1970. Note that our sampling changes only the amplitude, not the pattern, of diversity provided by the earlier bryozoan summary. Sepkoski (1993) reached the same conclusion from his surveys of marine fossil families taken 10 years apart.

The rate of mass extinctions is still the subject of debate (McLaren, 1996; MacLeod, 1996). The coarseness of the timescale as cited above does not allow us to determine unequivocally whether bryozoan extinctions are catastrophic, gradual or stepwise as discussed by Flessa (1990). Figure 3 presents the changes in diversity from stage to stage within periods. On a timescale based on stages, changes in diversity can be measured only to the length of a given stage, usually estimated to be millions of years. The number of conspicuous drops in diversity (extinctions exceed originations) have increased 3- or 4-fold compared to Figure 1. On the other hand, the diversity peaks are diminished when the stage data is 'standardized' by dividing by current estimates of the lengths of the stages, that is, species/million years. This is the simplest procedure to compensate for longer stages containing more species, which is inferred to lead to more evolution and more species.

We recognize four major drops in diversity and species/million years within the Paleozoic (Figure 3). These are end-Ordovician (end-Ashgill), end-Givetian within the Devonian, and end-Artinskian and end-Kazanian within the Permian. The end-Permian extinction is generally regarded as the largest mass-extinction event in the Phanerozoic (Erwin, 1993), the mother of all extinctions as Erwin (1996)

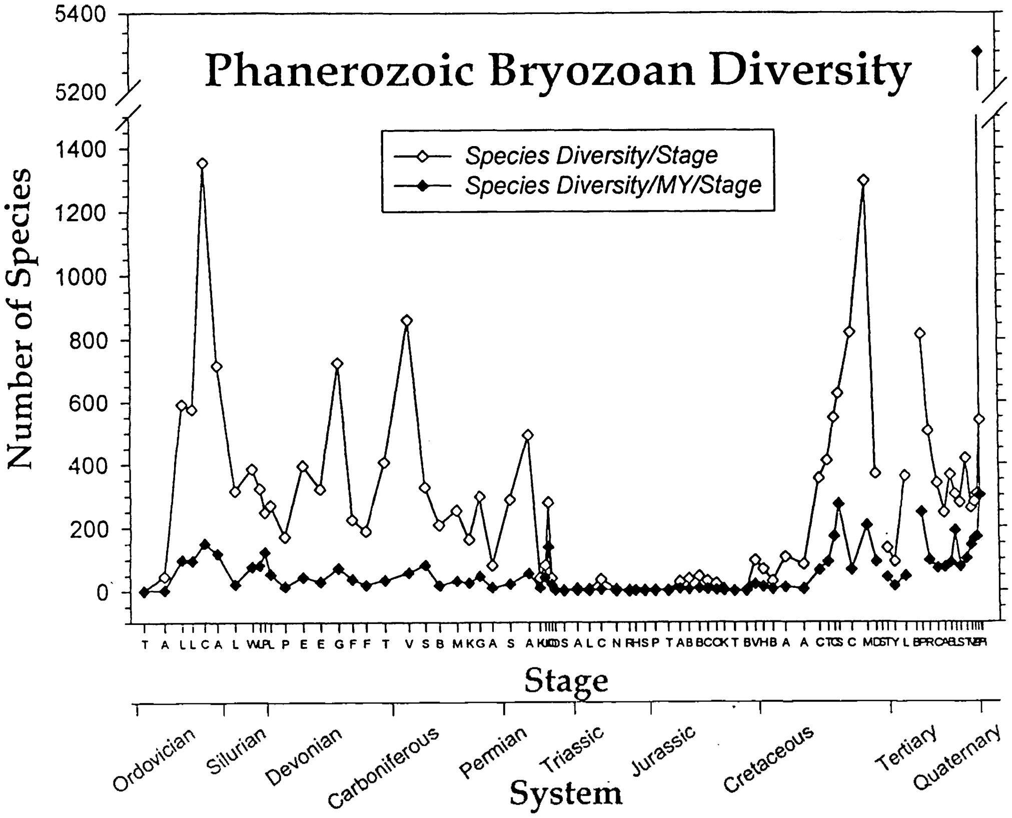


Figure 3. Bryozoan diversity for geologic stages. Upper curve is total stage diversity; lower curve is total stage diversity divided by stage length in millions of years.

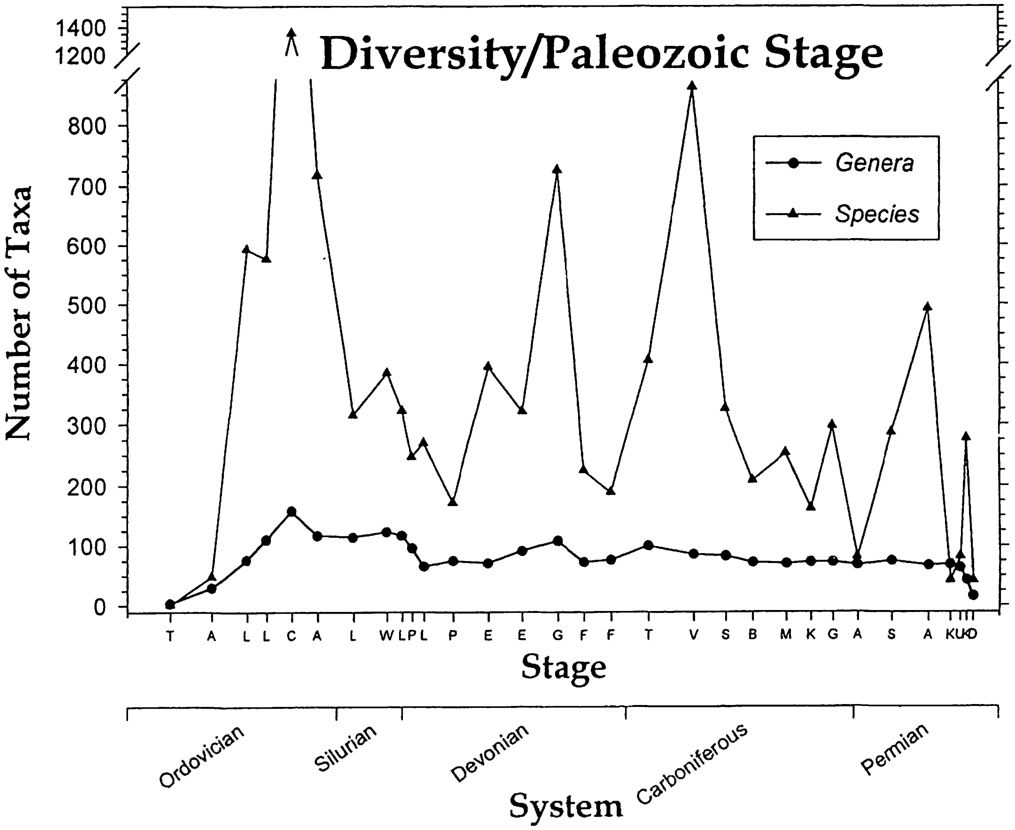


Figure 4. Comparison of bryozoan diversity for species and genera for Paleozoic stages. Generic data from Anstey and Pachut (1995).

suggests. Raup (1979) estimated that 88-95% of all late Permian species became extinct. Permian bryozoan diversity shows two declines (?extinction events) that occur well before the latest Permian stages, which have low bryozoan diversities.

None of the extinction events are visually striking when diversity is adjusted by the lengths of the respective stages (Figure 3), but the post-Paleozoic end-Maastrichtian (Cretaceous) event is larger than any bryozoan extinction in the Paleozoic except the end-Ordovician. The end-Santonian (Cretaceous) and end-Langhian (Miocene) events are probably artifacts of the relatively short durations of these stages.

The species record of bryozoans can be compared with the record of all fossil marine families reviewed by Benton (1995). Benton's figure of total extinction rate shows end-Ordovician (end-Ashgill), Devonian (end-Givetian, end-Famennian), Permian (end-Kazanian, end-Tatarian), end-Triassic, and end-Cretaceous as major events. The end-Famennian peak is not apparent in the bryozoan data. Of the post-Kazanian peaks, only the end-Cretaceous is apparent in the bryozoan record. An Artinskian event is not shown in Benton's summary of marine families.

Although bryozoan diversity was much reduced near the end of the Permian, a major change in the composition of bryozoan faunas occurred during the Triassic rather than at the beginning of the Triassic. The Triassic bryozoan fauna is characterized typically by Permian holdovers and a few new forms belonging to Paleozoic lineages. The modern bryozoan fauna developed in the Jurassic and early Cretaceous and did not gain dominance until the late Cretaceous. Bryozoans did not recover quickly from their Permian extinctions and did not reach Paleozoic diversities until the mid-Cretaceous (Figure 3).

The proposed causes of diversity patterns, mass extinctions, and evolutionary explosions (originations) has generated a large literature with much discussion and little concensus. It appears that individual mass extinctions may have been triggered by different causes or combinations of different causes and that it is prudent to evaluate each extinction event on its own merits.

The crust of the earth is apparently broken into plates that constantly move across the global surface. New oceanic crust is created at oceanic ridges as the plates pull apart and when oceanic crust collides with lighter continental crust the heavier oceanic crust sinks into deeper crustal layers and the lighter continents collide to form mountain ranges. This constant motion utimately allows all the continents to collide with one another to form supercontinents before the heat accumulating under the continents causes them to break apart forming new oceans and oceanic ridges so that the continental fragments move over the surface once again. In a general way this scenario fits the two Phanerozoic supercycles of hothouse-icehouse envisioned by Fischer (1984). The supercontinents tend to foster ice ages, especially if all or part is centered over a pole, and scattered continents tend to be associated with warm shallow seas with lots of carbonate (limestone and dolomite) deposition.

With respect to bryozoans, the end-Ordovician extinction may have been associated with a major late Ordovician glaciation. Although there is a late Devonian glaciation its association with lowered bryozoan diversity is less apparent than an association with widespread black shales interpreted as anoxic oceanic events that superceded the shallow carbonate seas of the middle Devonian. The Permian events are much more difficult to evaluate as they are part of a general decline in diversity that has been interpreted as the result of a major withdrawal of the seas due to the formation of the supercontinent Pangaea. The end-Cretaceous event does not appear to be associated with either glaciation or a major withdrawal of the sea and the effects of a major asteroid impact is accepted by many as a contributor to this extinction event. Schultz and D'Hondt (1996) suggest that the low impact angle of the Cretaceous-Tertiary (Chicxulub) event caused major disruptions in North America and lesser evidence of direct effects elsewhere, which might also explain the century long-debate (now settled) in Europe over the placement of the Cretaceous-Tertiary boundary above or below the Danian (earliest Paleocene stage).

In general, bryozoan diversity appears to be high at times of widespread carbonate-rich cratonic seas. Oceanic circulation undoubtedly has played a major role in climatic changes leading to extinctions and evolutionary explosions. Unfortunately almost nothing is known about oceanic circulation and its relation to continental masses in Paleozoic and early Mesozoic time.

Many studies have been compiled by different authors to show changes during Phanrozoic time in strontium, carbon, and sulphur isotopes as well as for changes in ice ages and withdrawals of the sea from shallow continental platforms (for example, Figure 1 in Martin, 1996). The pattern of bryozoan diversity in Figure 3 is not well correlated with any of these patterns but appears closest to an inferred sea level curve.

In summary, bryozoans generally are more abundant and diverse at times of widespread shallow continental seas, but the causes of major extinction events, including those involving bryozoans, is probably complex as no single cause appears to account for all events.

ACKNOWLEDGMENTS

We thank J. R. Dodd and N. G. Lane for their comments on an earlier version of this text.

CITATIONS

Anstey, R. L. and J. F. Pachut. 1995. Phylogeny, diversity history, and speciation in Paleozoic bryozoans, in D. H. Erwin and R. L. Anstey. New approaches to speciation in the fossil record. New York, Columbia University Press, p. 239-284.

Bassler, R. S. 1915. Bibliography index of American Ordovician and Silurian fossils. United States National Museum Bulletin 92, 2 vols, 1521 p.

Benton, M. J. 1995. Diversification and extinction in the history of life. Science, v. 268, p. 52-58.

Erwin, D. H. 1993. The great Paleozoic crisis: life and death in the Permian. New York, Columbia University Press, 327 p.

Erwin, D. H. 1996. The mother of mass extinctions. Scientific American, v. 275, no. 1, p. 72-78 [July 1996]

Fischer, A. G. 1984. The two Phanerozoic supercycles, in W. A. Berggren and J. A Van Couvering, eds. Catastrophes and earth history the new uniformitarianism. Priceton, New Jersey, Princeton University Press, p. 129-150.

Flessa, K. W. 1990. The "facts" of mass extinctions. in V. L. Sharpton and P. D. Ward, eds., Global catastrophes in earth history an interdisciplinary conference on impacts, volcanism, and mass mortality. Geological Soceity of America Special Paper 247, p. 1-7.

Fordham, B. G. 1992. Chronometric calibration of Mid-Ordovician to Tournaisian conodont zones: a compilation form recent graphic-correlation and isotope studies. Geological Magazine, v. 129, p. 709-721.

Gradstein, F. M. and J. Ogg. 1996. A Phanerozoic time scale. Episodes, v. 19, nos. 1 & 2, p. 3-5 and chart.

Horowitz, A. S. and J. F. Pachut. 1993. Specific, generic, and familial diversity of Devonian bryozoans. Journal of Paleontology, v. 67, p. 42-52.

Horowitz, A. S. and J. F. Pachut. 1996. Tabulating Cenozoic bryozoan diveraity: a progress report. Proceedings of the 10th International Bryozoology Conference, Wellington, New Zealand.

Horowitz, A. S., J. F. Pachut and R. L. Anstey. 1996. Devonian bryozoan diversity, extinctions, and originations. Journal of Paleontology, v. 70, p. 373-380.

MacLeod, N. 1996. K/T redux. Paleobiology, v. 22, p. 311-317.

McKinney, F. K. 1969. Bibliography and list (1900-1965) of the families Constellariidae and Dianulitidae (Ectoprocta, Order Cystoporata). Southeastern Geology, v. 10, p. 175-184.

McKinney, F. K. 1974. Bibliography and catalogue (1900-1969) of the Trepostomata (Phylum Ectoprocta). Southeastern Geology Special Publication Number 4, 147 p.

McLaren, D. J. 1996. Mass extinctions are rapid events. Palaios, v. 11, no. 5, 2 p.

Martin, R. E. 1996. Secular increase in nutrient levels though the Phanerozoic: implications for productivity, biomass, and diversity of the marine biosphere. Palaios, v. 11, p. 209-219.

Nickles, J. M. and R. S. Bassler. 1900. A synopsis of American fossil Bryozoa including bibliography and synonym. United States Geological Survey Bulletin 173, 663 p.

Raup, D. M. 1976. Species diversity in the Phanerozoic: a tabulation. Paleobiology, v. 2, p. 279-288.

Raup, D. M. 1979. Size of the Permo-Triassic bottleneck and its evolutionary implications. Science, v. 206, p. 217-218 [12 October 1979]

Rudwick, M. J. S. 1972. The meaning of fossils. London, Macdonald and New York, American Elsevier Inc., 287 p.

Schultz, P. H. and Steven D'Hondt. 1996. Cretaceous-Tertiary (Chicxulub) impact angle and its consequences. Geology, v. 24, p. 963-967.

Sepkoski, J. J., Jr. 1993. Ten years in the library: new data confirm paleontological pattern. Paleobiology, v. 19, p. 43-51.

Sepkoski, J. J., Jr. 1981. R. K. Bambach, D. M. Raup, and J. W. Valentine. 1981. Phanerozoic marine diversity: a strong signal from the fossil recored. Nature, v. 293, p. 435-437.

Sherborn, C. D. 1902. Index animalium sive index nominum quae ab A.S. MDCCLVIII generibus et speciebus animalium imposita sunt. Cantabrigiae, lix + 1195 p.

Sherborn, C. C. 1922-1933. Index animalium sive index nominum quae ab A.S. MCDCCLVII generibus et speciebus animalium imposita sunt. The Trustees of the British Museum, London, cxxxvi + 7056 p.

IS THE TULLY MONSTER REALLY EXTINCT

Jim Konecny
3036 Geronimo Road
Prescott, AZ 86301

The subject of extinction is a very complex issue. Oh, yes, the answer as to why an organism became extinct is simple - an organism became extinct because it could not adjust to a changing environment. Now we get to the complexity of the subject. What was the nature of that change? What factor brought about that change?

There are many elements that constitute environmental change; an increase in competition for food; an increase in competition for space; a change in climate - warmer, colder, dryer, wetter; atmospheric change - percent of oxygen, CO2, etc.; in the case of marine organisms, a change in salinity and/or other chemicals; change in water conditions i.e. clarity - to name a few. Changes in any one of these conditions can have a profound effect on the habitat. A habitat can encompass any size area from a small lake or stream to half of a continent. Every creature, every plant on this earth has evolved within a certain complex set of conditions. If these conditions are altered in any way, a species may lose it's ability to exist. However, nature can be kind with it's infinitely variable processes. Some creatures are more adaptable than others. For example, the opossum of North America has been constantly increasing it's range northward whereas there are some fish in Arizona that can exist in only a restricted area of the Colorado River.

To illustrate how complicated this subject can be, let us use the Tully Monster (Tullimonstrum gregarium) as an example. Remains of the Tully Monster have been found only in the middle Pennsylvanian Carbondale Formation, Francis Creek Shale Member of Illinois. They have been found in only three locations near the towns of Morris, Essex and Astoria. Morris and Essex, located in the famous Mazon Creek Area, are about 25 mi. (40km.) apart; Astoria is about 125 mi. (200km.) to the southwest.

The body structure of the Tully Monster is very unique, to say the least (Fig.1).

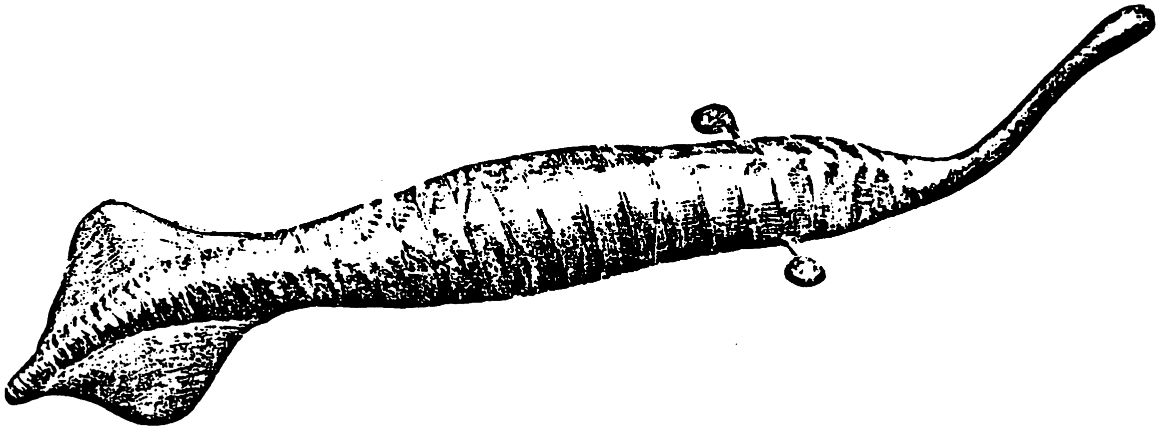


Fig.1 Tullimonstrum gregarium
A reconstruction

It was originally referred to as a wormlike fossil and was described as follows "Abstract: Tullimonstrum gregarium was a common, possibly marine, invertebrate in certain shallow, off-shore 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." (Richardson, 1966). This unusual body plan has not been found in fossils in younger or older deposits.

Foster (1979b) compares the Tully to modern heteropods, a form of shell-less planktonic gastropods (Fig. 2). He has specifically made reference to the resemblance to the genus Pterotrachea. In fact, Foster reclassified Tullimonstrum gregarium from indet to Gastropoda.

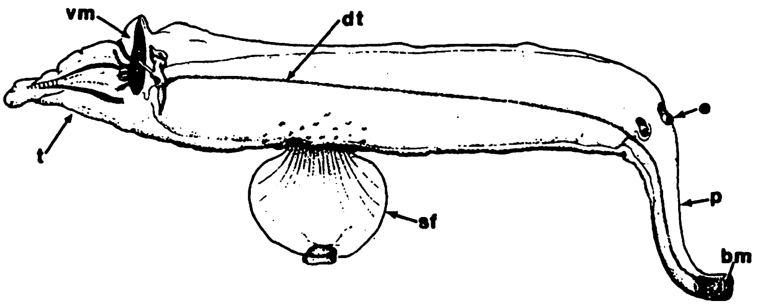


Fig. 2 *Diagrammatic sketch of Pterotrachea coronata. This specimen is upside down compared to its normal orientation in the water. X 0.8. Abbreviations: (bm) buccal mass; (dt) digestive tract; (e) eye; (p) proboscis; (sf) swimming fin; (t) tail; (vm) visceral mass.*

Copied from Foster, 1979b.

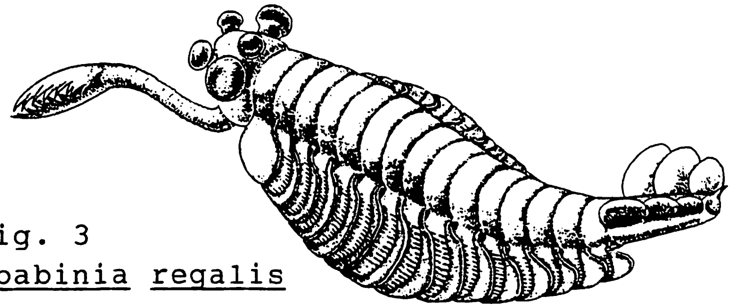


Fig. 3
Opabinia regalis

Copied from Briggs, et at, 1994.

He also made reference to the vague similarity to Opabinia from the lower Cambrian Burgess Shale (Fig.3). Wittington, one of the experts on the Burgess Shale biota, regards Opabinia as belonging to the ancestral stock that gave rise to the arthropods and annelids. It is therefore unlikely that Opabinia regalis is ancestral to Tullimonstrum gregarium. Unless of course, as was originally suggested by Richardson, the Tully actually was an annelid and not a gastropod. However if, as Foster suggests, Tullimonstrum is ancestral to the heteropods, this brings up more questions than answers. Where were these animals between the Pennsylvanian and the present time? No fossils even remotely resembling the Tully have been found in this interim period. Why? Is it because the fossil record is incomplete? This is not likely since the fauna associated with the Tully, annelids, crustaceans, gastropods, medusae, etc., is found in all ages of rock in this interim period. Even the creatures who, like the Tully Monster, lacked hard parts are found preserved in these sediments.

The spatial limitation of the Tully Monster was a definate disadvantage to it's continued existance. The smaller the habitat area the greater the chances of it's disruption or destruction.

The Mazon Creek Area is rich in both floral and faunal fossil assemblages, with over 500 plant and animal species having been recorded thus far. Terrestrial, marine, brackish and fresh water biota are represented in this assemblage. The extent of the ocean during Francis Creek time has been well established (Johnson & Richardson, 1966, 1969; Shabica 1970; Baird, 1979). Location of the shoreline is shown in (Fig.4). Note that our three locations are situated on this ancient shore.

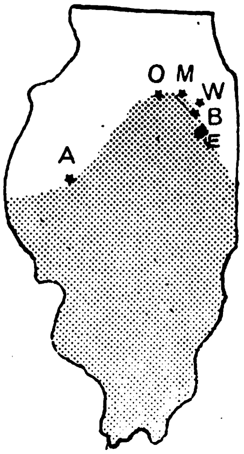


Fig.4 Approximate extent of the sea. A: Astoria; O: Ottawa; M: Morris; W: Wilmington; B: Braidwood; E: Essex. After Richardson and Johnson, 1969.

Two seperate assemblages have been established by Johnson and Richardson; the Braidwood Biota which consists of terrestrial and fresh water species and the Essex Biota which consists of marine species. Both contain some of the transitional brackish species. The Mazon Creek Area has been interpreted as a deltaic environment (Richardson & Johnson, 1969; and Shabica, 1979.) and since the faunal composition at Astoria is similar to that at the Mazon Creek Area we can conclude that the environment was the same. A lower delta plain, delta margin (lagoonal) and delta front are all represented in the sediment complex. The Tully Monster was an inhabitant of the open sea in a near shore environment (Foster, 1979b). Studies have shown that the deposition occurred in a specific uninterrupted sequence similar to present day deltaic action. Floods and storm surges would have had a major effect on the quality and salinity of the water. Since these weather conditions were regular occurrences, the biota must have been able to adjust to these sudden, short term changes. Tropical storms, i.e. hurricanes, though devastating, are not known to have wiped out any animal populations and since there is very little evidence at Mazon Creek of fragmentation of delicate bodies it appears that catastrophic storm conditions were rarely present.

During Pennsylvanian time the North American continent was subjected to at least 50 marine transgressions (Dott & Batten). Several of these transgressions did occupy the area of our subject. No doubt some of these occurred at a slow rate and some at a fast rate, resulting in differential sedimentation rates. Some authors claim that fluctuations of sea level are evident in the depositional sequence. Shabica (1979) states

"Vertical tree trunks preserved in living position are evidence for rapid sedimentation." However, stratigraphic examination of the head wall in the mine near Essex showed no indication that this rapid sedimentation had any effect on the biota. Some cluster patterns of distribution were observed in collecting on the spoil heaps. In as much as this may be an indication of localized communities, this information is of no stratigraphic value. Presently the compiled evidence indicates that the cyclic depositional sequence occurred under normal sea level conditions.

Foster suggested that <u>Tullimonstrum</u> <u>gregarium</u> was an active marine carnivore. The animals that the Tully Monster apparently preyed upon - fish, medusae, polychaetes, etc. - have withstood the ravages of extinction. It is therefore unlikely that a loss of food supply was the cause of <u>Tullimonstrum</u>'s demise.

There is no evidence of any type of catastrophic event taking place at this time. Whatever caused the Tully Monster's downfall is not apparent in the record written in the rocks. The latest theory on the dinosaurs is that they did not become extinct, but rather that they evolved into birds. Perhaps Foster (1979b) is correct, <u>Tullimonstrum</u> <u>gregarium</u> didn't go extinct, he merely evolved into present day heteropods. Personally I like to think that the Tully Monster appeared on the scene suddenly and just as suddenly disappeared - without a trace.

REFERENCES:

Baird, Gordon C. 1979. Lithology and Fossil Distribution, Francis Creek Shale in Northeastern Illinois. In: Mazon Creek Fossils, Matthew H. Nitecki, Ed., Academic Press.

Briggs, Derek E.G., Douglass H. Erwin and Frederick J. Collier. 1994. The fossils of the Burgess Shale. Smithsonian Institution.

Carman, Mary R. 1989. The Monster of Illinois. In: Rocks and Minerals, Vol. 64, No. 1, Jan/Feb 1989.

Dott, Robert H., Jr. and Roger L. Batten. 1976. Evolution of the Earth. McGraw-Hill Book Co.

Foster, Merrill W. 1979a. Soft Bodied Coelenterates in the Pennsylvanian of Illinois. In: Mazon Creek Fossils, Matthew H. Nitecki, Ed. Academic Press.

Foster, Merrill W. 1979b. A Reappraisal of Tullimonstrum gregarium. In: Mazon Creek Fossils. Matthew H. Nitecki, Ed. Academic Press.

Johnson, Ralph Gordon and Eugene S. Richardson, Jr. 1966. A Remarkable Pennsylvanian Fauna from the Mazon Creek Area, Illinois. Journal of Geology, Vol. 74, No. 5, Sept. 1966.

Richardson, Eugene S., Jr. 1966. Wormlike Fossil from the Pennsylvanian of Illinois. Science, Vol. 151, No.3706, Jan. 7, 1966.

Richardson, Eugene S., Jr. and Ralph Gordon Johnson. 1969. The Mazon Creek Faunas. Proceedings of the North American Paleontological Convention, Sept. 1969.

Shabica, Charles W. 1970. Depositional Environments in the Francis Creek Shale. In: Illinois State Geological Survey, Guidebook Series 8.

Shabica, Charles W. 1979. Pennsylvanian Sedimentation in Northern Illinois: Examination of Delta Models. In: Mazon Creek Fossils. Matthew H. Nitecki, Ed. Academic Press.

Volume 37, Number 7 July, 1966

BULLETIN **FIELD MUSEUM OF NATURAL HISTORY**

CYSTOIDS

Don Bissett
3925 Dust Commander Drive
Hamilton, Ohio 45011

Cystoids are curious-looking creatures. They occur infrequently, and such rare finds are little understood or appreciated. When I found my first, I had little idea of how valuable they could be as collector's items and as items of scientific interest.

Cystoids are primitive stemmed echinoderms. Their chief characteristics are the pores (apparently involved in respiration) on the body plates and the sparse food gathering brachioles. The body is sacklike, generally with numerous irregularly arranged plates. Body symmetry is often difficult to identify.

They flourished in Ordovician and Silurian, gradually becoming extinct at the end of the Devonian. Their extinction can be traced to life style. They generally existed as small populations in restricted geographic areas. They apparently favored abundant food sources and particular depths and bottom conditions. They evolved closely attuned to the ecological factors in a specific area and could not adapt to change in that environment.

A favored environment must have existed in what is now the Newpoint Stone Company Quarry in Napoleon, Ripley County, Indiana. Over 400 million years ago, a Silurian sea covering this small area teemed with echinoderms, brachiopods corals, etc. A thin band of shale (Osgood Shale, Formation Niagaran Series) now covers them. Even within the limited area of the quarry, there are clearly favored environments. One end of the quarry abounds with cystoid remains. One hundred yards across the pit, the shale is devoid of cystoids but is still crammed with the other fauna.

The discovery in recent years of the echinoderm content of this old seabed has introduced to paleontology a raft of new species. But these discoveries were not made overnight. Dan Cooper, Bruce Gibson, and I spent hundreds of hours surface collecting, digging, and sifting shale to make these finds. Even with all that effort,

some species are known from but single specimens.
They range in size from one-eighth inch micros to monsters measuring half a foot. By far, predominant species is Holocystites scutellatus . Considerably less common are other species of Holocystites , (Megacystites), Triamara sp., Pentacystites sp., Caryocrinites sp., Trematocystis sp., and Paulocystis sp., to name the majority.

None of the cystoids from this locality are preserved with arms. However, arm attachment sites are visible around the oral area. Species like Caryocrinites grew on stems while others (H. scutellatus "budded off" from their stems early in life to become "free floaters" or rested on the bottom. Still others (Paulocystis) attached directly to the bottom with a wide base. (Representatives are shown in the accompanying sketches.)

The most exciting finds are the rare, previously unknown species. My favorite is also a new genus: Paulocystis bissetti. It has a very wide base for botton attachment. In contrast to the usual five-fold symmetry of echinoderm feeding apparatus, this genus has a square oral area and only four ambulacra (feeding grooves). The Trematocystis sp. also fall into this category of square oral area.

The Napoleon quarry produced cystoids in quanity for only a short time -- about two years. The rich pocket has come and gone. The remaining prolific shale from the pocket has been dumped and buried under yards of barren overburden as quarrying continues. I was at the right place at the right time -- Two years out of 400 million.

Triamara cutleri, n. sp.

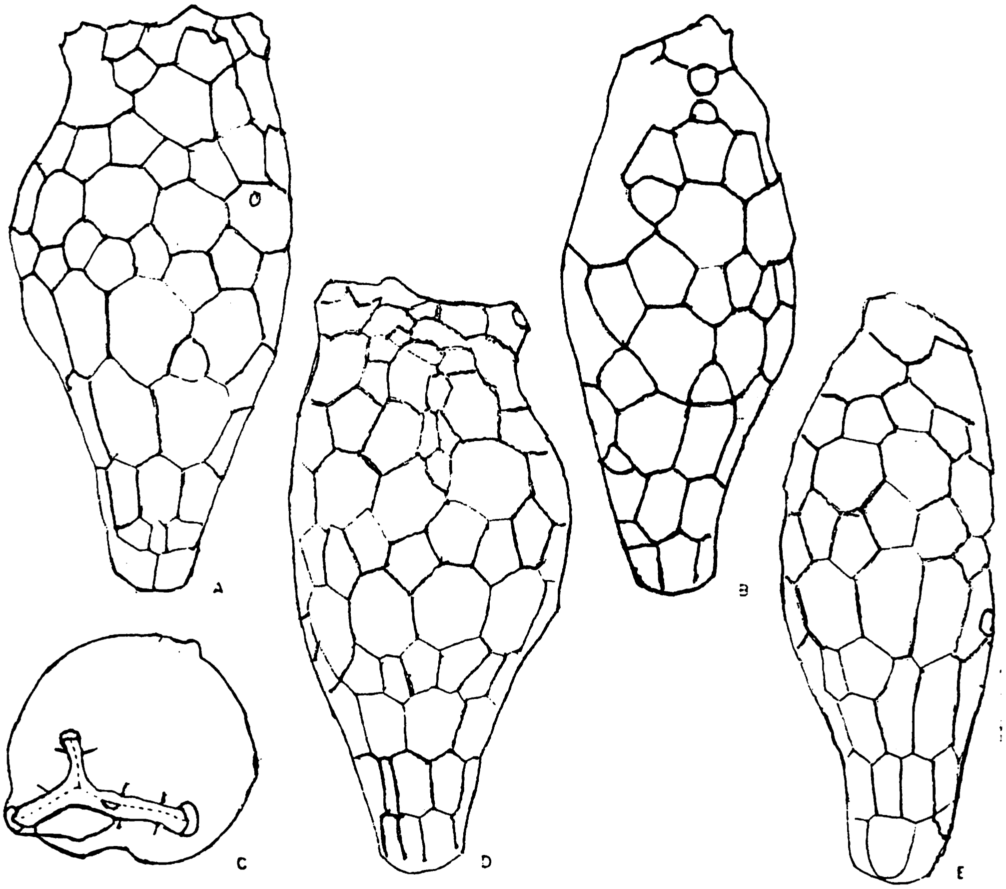
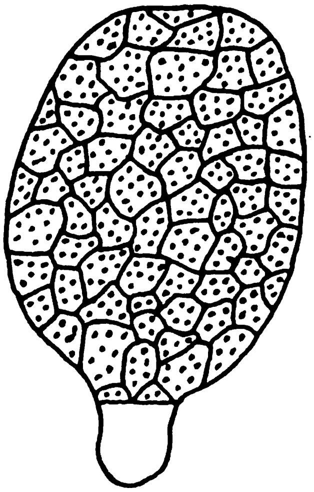


Fig.1 - Plate diagrams of Trimara cutleri, n. sp. A, Abanal surface, boring stippled; B, lateral surface, anal surface to right; C, ambulacral surface, dashed lines indicate bottom of grooves; peristome indicated in longest grooves, anal surface faces downward; D, anal surface; peripheral stippled; E, right lateral surface; anal surface to left. Approx. X 1

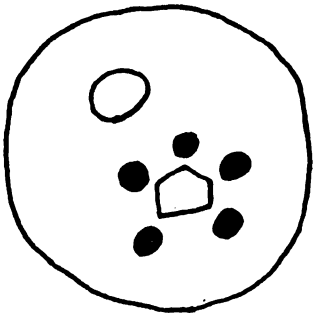
The specimen here illustrated from the Silurian, Osgood Formation, Niagaran Series, Napoleon, is designated the holotype.

The calyx is elongate, unsymmetically bulb-shaped and tapering to a cylindrical, bluntly rounded basal termination.

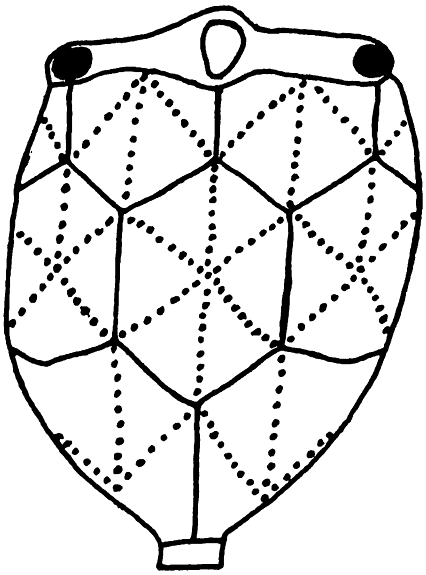


side view

Holocystites scutellatus

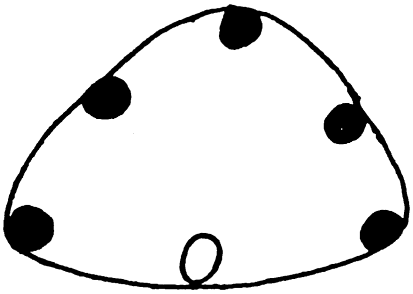


top view

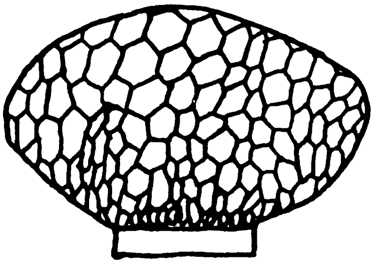


side view

Caryocrinites ornatus

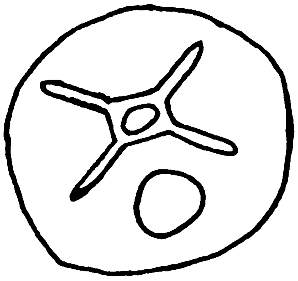


top view



side view

Paulocystis bissetti



top view

EXTINCTION

Concepts, Generalities, And Musings

Marc Behrendt
421 S. Columbus St.
Somerset, OH 43783
614-743-2818

1. In order of magnitude,The 5 worst mass extinctions occured:

End of Permian

End of Ordovician

End of Triassic

During Late Devonian

End of Cretaceous
(1)

2. "Mass Extinction periodically wipe out large segments of life without prior evolutionary history, adaptation, or other evolutionary changes which may be irrelevant to survival during a mass extinction." (1)
In other words, during a mass extinction it dosen't necessarily matter who you are, where you live, what you do for a living, or how important you are to the community extinction is unbiased.

3. The Permian extinction affected filter feeders which attached to substrate and the passive carnivores. Active predators such as fish and cephalopods were less affected. The Paleozoic Era ended with the immobile herbivores, scavengers, sessile (attached) filter feeders, while the Mesozoic Era began with the mobile bivalves, gastropods, crabs, more predatory cephalopods (ie. ammonites) and swimming predators (ie. vertebrates - fish and reptiles.) (2)

4. Permian trilobites appear to have been restricted to reef habitats, requiring a firm substrate and clear water with adequate nutrients with no mud, silt, or sediment flux. Reef specific invertebrates suffered heavy losses or complete extinction at the end of the Permian. Other reef groups suffering major losses including the articulated brachiopods, tabulate and rugose corals, stenlaemate bryozoan, crinoids, blastoids, with starfish, graptolites, and cephalopod numbers decreasing significantly. (1,2)

5. A stable environment and community yield high diversity of specialized species. Variable environments yield low diversity of generalized and opportunistic species. (2)
A modern day example of this concept can be seen with ponds and puddles. A pond is a stable environment and containes many different kinds of life, possessing a complex food web. A large puddle is an unstable environment, containing fewer species with a very basic food chain.

6. Survivors of a mass extinction are more likely to be generalized opportunists, adapted to fluctuating and unpredictable conditions. Specialized species are prone to die off during a period of change. (2)

7. Ordovician, Late Devonian and Permain extinctions, among others, may have been related to a dropping sea leavel. Continental movement and the altered ocean currents created changing weather and climate patterns. (3,4)

We are familiar with the Pacific's El Nino current and the widespread effects it has on North America. Imagine the long term effects if the El Nino would become a permanent condition!

8. A drop in sea level will increase climate variations with more storms, thus creating more sediment. Along with the muddy habitat unsuitable for filter feeders, competition for suitable shallow water habitats would increase significantly. Destroyed continental shelf habitats and poorly oxygenated water from the deep mixing with the little shallow water caused highly stressed or uninhabitable habitats. Marine extinctions increase when comptition increases for a profoundly reduced habitat area. Pelegic and fresh water species are less affected by sea level fluctuations. (4,5)

9. The trilobite extinction had begun long before the Permian period. The number of trilobite families dropped from 67 during the Ordovician to 16 in the Silurian.

Number of trilobite families per period:

Cambrian	102	
Ordovician	67	
Silurian	16	
Devonian	14	
Mississippian	4	
Pennsylvanian	3	
Permian	1	(6)

10. During the Cambrian, most species come up to the Cambrian biomere boundry then disappear. 3 other scenarios also occured: some species went through, but only a meter or two then died out; others continued to survive, but never proliferated; some got through and radiated into new species. Typically, the successful transition species were primitive morphologic forms, much like the species that made it through the previous boundry. It is assumed these species came up from the deep waters, traveling upslope to fill in open niches. This pattern occured several times.

(7)

And a musing...

Mass Extinction is much like a business that is reorganizing. Consider this comparison. a business operates with many employees filling specific niches within the organization, from entry level minium wage jobs to corporate executives. Everybody exists in a comfortable and stable environment. Then some minor or major element of chaos occured, shaking the function of the entire structure. Suppose insufficient capital was earned to cover all the paychecks and bills. The business must adjust to maintain solvency. Positions will be eliminated and repercussions felt all the way to the top of the corporate ladder. Employees with multiple skills would likely remain employed while those with one specialized skill would be at risk of losing their positions.

If that same business meets with a catastrophic disaster such as a fire, a buyout, or bankruptcy, a "mass extinction" will occur. Most or all jobs will be eliminated, regardless of seniority or job description. If the business continues to exists, only those employees who are able to survive on meager salaries, those who can perform many duties, and those who somehow just manage to hang on, will continue. And there is no guarantee the business will survive regardless of their efforts. Should the business again become strong, it will have a new structure with mostly new employees filling the open niches remaining from the previous adminstration along with the newly developed niches.

Lets change the business to an ecosystem, the money to nutrients, the corporate ladder to a food chain, and the comparison is complete. Physical and environmental changes, new competition, increasing specialization of competitors, food and energy resourses, and changing habitats all play definitive roles in the game of survival, whether it is a business or an ecosystem. These elements cannot be controlled, or even anticipated. When the challenge is made, then once again the generalists, the opportunists, and the survivers will build a new plan to fit the conditions.

Bibliography

1. The Great Paleozoic Crisis - Life and Death in the Permian by Douglas H. Erwin, Columbia University Press 1993

2. Evolutionary Paleoecology of the Marine Biosphere by James Valentine, Prentice Hall Inc. 1973

3. The Ecology of Fossils edited by W.S. Mckerrow, MIT Press 1978

4. Fossils and Climate edited by P.J. Brenchley, John Wiley and Sons 1984

5. The Biomere Problem: Evolution of an Idea by Allison R. Palmer, Journal of Paleontology Vol.58 No.3 May 1984

6. Trilobites by Riccardo Levi-Setti, University of Chicago Press 1993

7. "Cambrian Biomeres" by Pete Palmer, The Mass Extinction Debates: How Science Works in a Crisis, edited by William Glen, Stanford University Press 1994

Rockford Ammonoids

Also known as The Kinderhookian Ammonoids

Margaret E. Kahrs
9145 W. U.S. Hwy. 50 E.
Seymour, IN 47274

INTRODUCTION

The Rockford Limestone exposure located in the East Fork of White River At Rockford, at the north edge of Seymour,Indiana.

Early reports were that the site was destroyed by the dam being constructed over the exposure, and that the ammonoids were not observed in place.

The exposure which yielded hundreds of the elusive ammonoids was approximately 300 yards down stream from the dam and were observed in place and in matrix. Apparently there was a small exposure up stream from the dam, which I did not visit. The site is now under tons and tons of refuse old appliances, cement, asphalt and debris dumped there by a resident, the city of Seymour and the Jackson County Highway Department.

STRATIGRAPHY

Rockford Limestone Formation is Mississippian age, Kinderhookian Series, Borden Group. It ranges in thickness from a few inches to three Feet in the exposure at Rockford. This fomation consists of a greenish-gray crystalline limestone mottled with dusty green which overlies the New Albany Shale. In some places it is dolomitic. At other localities it overlies six inches of green shale called Jacobs Chapel Shale which overlies the New Albany Shale. The Rockford underlies the New Providence Shale of the Borden Group. The classic Indiana Rockford ammonoid fauna was, at that time thought to be restricted to basal Osagean Series. Conodonts from the Rockford Limestone were extensively studied by Rexford and Scott (1964). This investigation demonstrated that the Kinderhookian-Osagean boundry falls within the Rockford Limestone.

The Rockford Limestone of southeastern Indiana has produced the most prolific and well-known Lower Mississippian ammonoids in North America. Thousands of specimens were collected during the late 1800's from the "goniatite beds" at the type section near Rockford, Indiana.

In addition to the type locality, The Rockford Limestone has yielded ammonoids at three other localities. Gutschick and Trackman (1957) described a small collection of ammonoids from northeastern Indiana, representing the species Gattendorfia alteri and Prodromites gorbyi. Two specimens referred to Imitoceras rotatorium and Muensteroceras parallelum were reported by Lineback (1963) from a second locality approximately 15 miles southeast of the type Rockford. The reports from 1957, 1963, and 1964 concur, the type locality falls within the Kinderhookian Series.

SYSTEMATICS

Ammonoidea are coiled cephalopods with marginal siphuncles and fluted septa. They derived from the Early Devonian and reached their peak during the Mesazoic era, but vanished before the Cenozoic era. They are recognized by their suture patterns.

The Goniatite, as an example of a simple ammonoid. The siphuncle of a goniatite is much like the Nautilus. It is composed of short backward painting septal necks and delicate, long cylindrical connecting rings. Other ammonoids differ from Goniatites in the pattern of the sutures, positions and character of the siphuncle. Sutures on Goniatites are somewhat simple compared to other ammonoids.

The siphuncle is a tube which runs through the chamber of the shell it is the organ which enables the cephalopod to control bouyancy. It removes fluid from the septum and adds gas to these chambers so the animal can stay at any level it wants to in the water. It can be seen from the outside (ventral) edge of the shell on an Ammonoid but on the inside of a Nautiloid, and cannot readily be seen.

Solenochilus springeri (Hyatt) Loosely coiled or whorls faintly impressed; shell surface smooth; mature aperture modified; angular umbilical shoulders expanded into prominent lateral spines; septal necks relatively long on ventral surface.

Imitoceras rotatorium (de Koninck) Goniatite, Conch sublenticular umbilicus small; sutures simple, forming eight lobes, all of which are undivided.

Muensteroceras oweni (Hall) Evolute, compressed or discoidal goniatite with highly arched whorls and moderately wide umbilicus; sutures with angular, superior lateral lobe and acute second lateral lobe outside umbilicus; ventral lobe narrow with small notched saddle surface smooth.

Muensteroceras parallelum (Hall) Gradual development; compressed discoidal goniatite with highly arched whorls and narrow umbilicus ; sutures with angular, superior lateral lobes and acute second lateral lobe outside umbilicus; ventral lobe narrow; surface smooth

Protocanites lyoni (Meek & Worthen) Goniatite, Conch with whorls compressed, impressed dorsally, rounded ventrally; umbilicus large, open; umbilical shoulders rounded, surface smooth.

OBSERVATIONS

There is a small town just northeast of Henryville, Indiana by the name of Kinderhook. Joce and Rudy Turner and me were in that vicinity scouting out Conodonts when I spotted the name. We were searching for the Jacobs Chapel Shale, and found it (the shale I mean). We did not go looking for a town, fossils are always first.

There was an article in one of the Earth Science publications several years ago stating that the locals would find the ammonoids and called them "snake rocks" children use to throw them at each other.

REFERENCES

Lower Carboniferous Ammonoid assemblages of North America; W. L. Manger (1979)

Kinderhookian Ammonoids; W. M. Furnish, and W. L. Manger (1973)

Age of the Rockford Cephalopod Fauna; J.A. Lineback; (1963

The Kinderhookian-Osagean Boundry; Rexroad and Scott; (1962)

Index Fossils of North America, Shimer and Shrock; (1972)

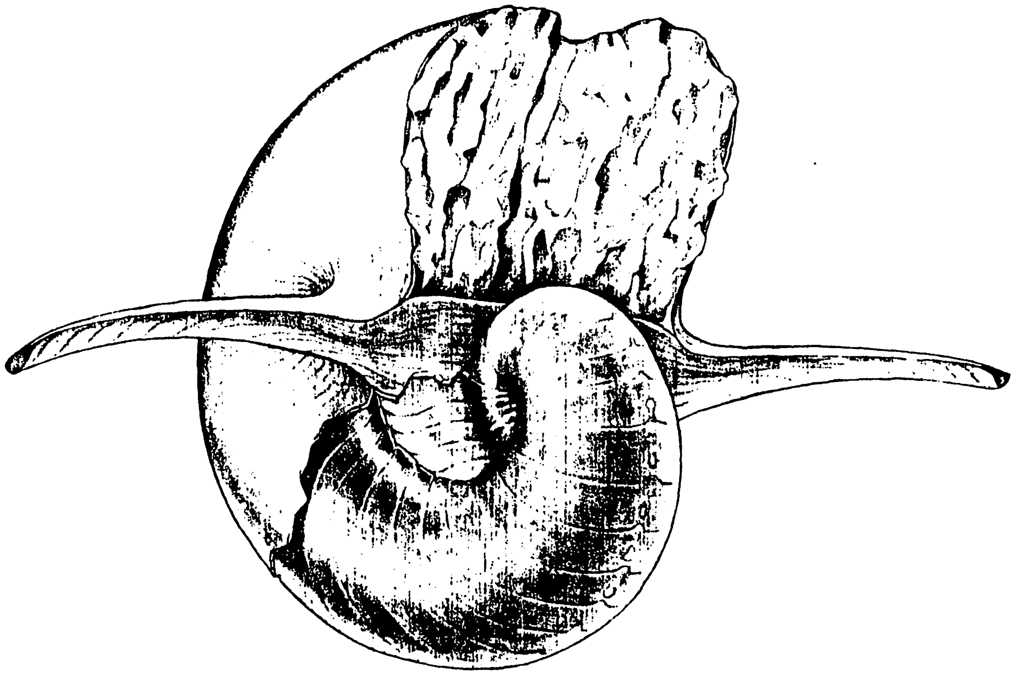


FIG. 319. *_Solenochilus springeri_ (WHITE & ST. JOHN) (Aipocerataceae-Solenochilidae) (p. _K_441).

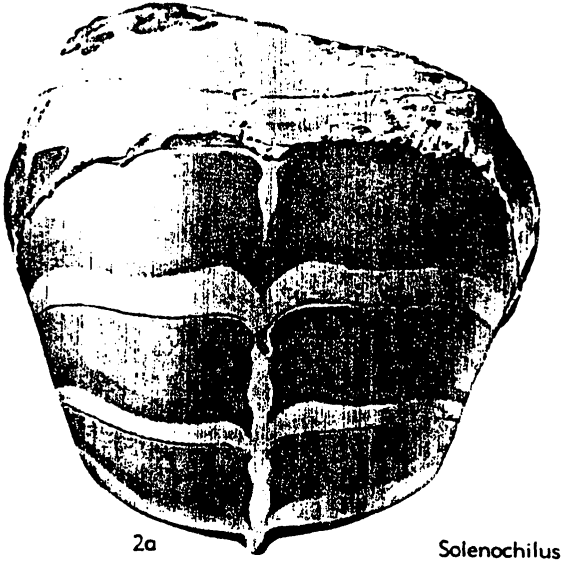


FIG. 318. Aipocerataceae (Aipoceratidae, Solenochilidae)

Superfamily
AIPOCERATACEAE
Hyatt, 1883

[_nom. transl._ SHIMANSKIY, 1962 (_ex_ Aipoceratidae HYATT, 1883)] [=Solenocheilidae HYATT, 1893; Solenochilida MILLER, DUNBAR, & CONDRA, 1933; Solenochilida FLOWER in FLOWER & KUMMEL, 1950 (order); Solenochilaceae SHIMANSKIY, 1957 (_ex_ Solenocheilidae HYATT, 1893)] [Materials for this superfamily prepared by W. M. FURNISH & BRIAN F. GLENISTER, State University of Iowa]

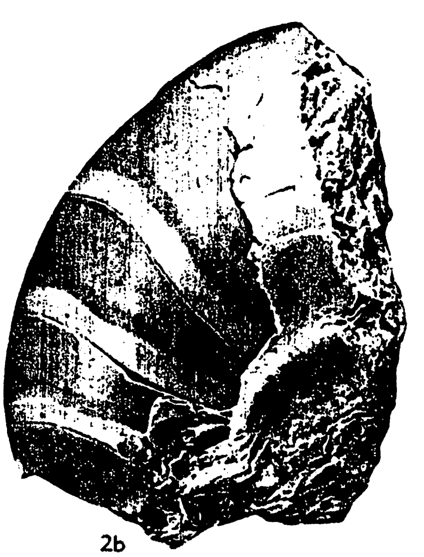
Conch rapidly expanding, cyrtoconic to coiled, whorls rounded to flattened or possibly impressed dorsally; shell surface smooth to ribbed; modified mature aperture known in most forms; sutures nearly straight; siphuncle marginal and ventral; septal necks orthochoanitic on ventral surface and orthochoanitic to cyrtochoanitic on dorsal side. _L.Carb.(Miss.)-L.Perm._

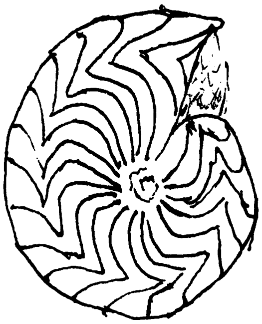
Family AIPOCERATIDAE Hyatt, 1883

[=Solenocheilidae HYATT, 1893 (_partim_); Solenochilidae MILLER, DUNBAR, & CONDRA, 1933 (_partim_)]

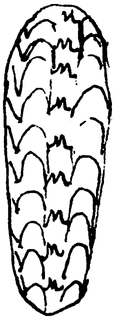
Loosely coiled or whorls faintly impressed; shell surface smooth; mature aperture modified. _L.Carb.(Miss.)-U.Carb._

Aipoceras HYATT, 1884, p. 296 [*_Gyroceras gibberosum_ DEKONINCK, 1880, p. 6; OD]. Loosely





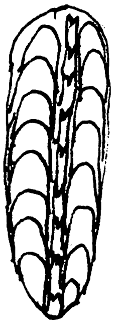
Lateral view



Ventral view

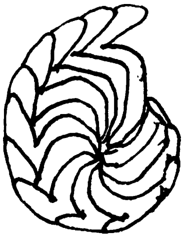
Muensteroceras oweni

Lateral view

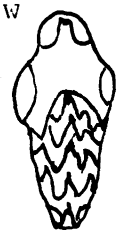


Ventral view

Muensteroceras parallelum

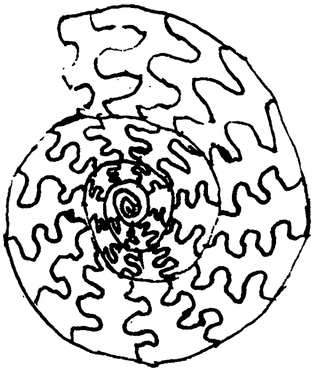


Lateral view



Ventral view

Imitoceras rotatorium

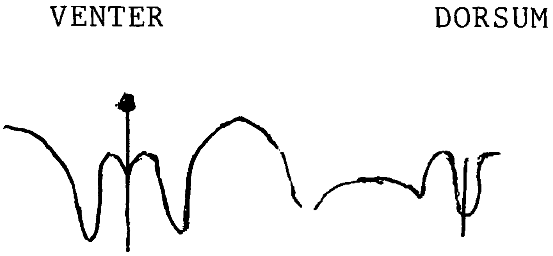


Lateral view

Ventral view

Protocanites lyoni

GONIATITIC
sutures



Suture lines of most Paleozoic Ammonoids.

CERATITIC
sutures

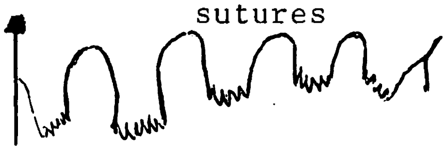
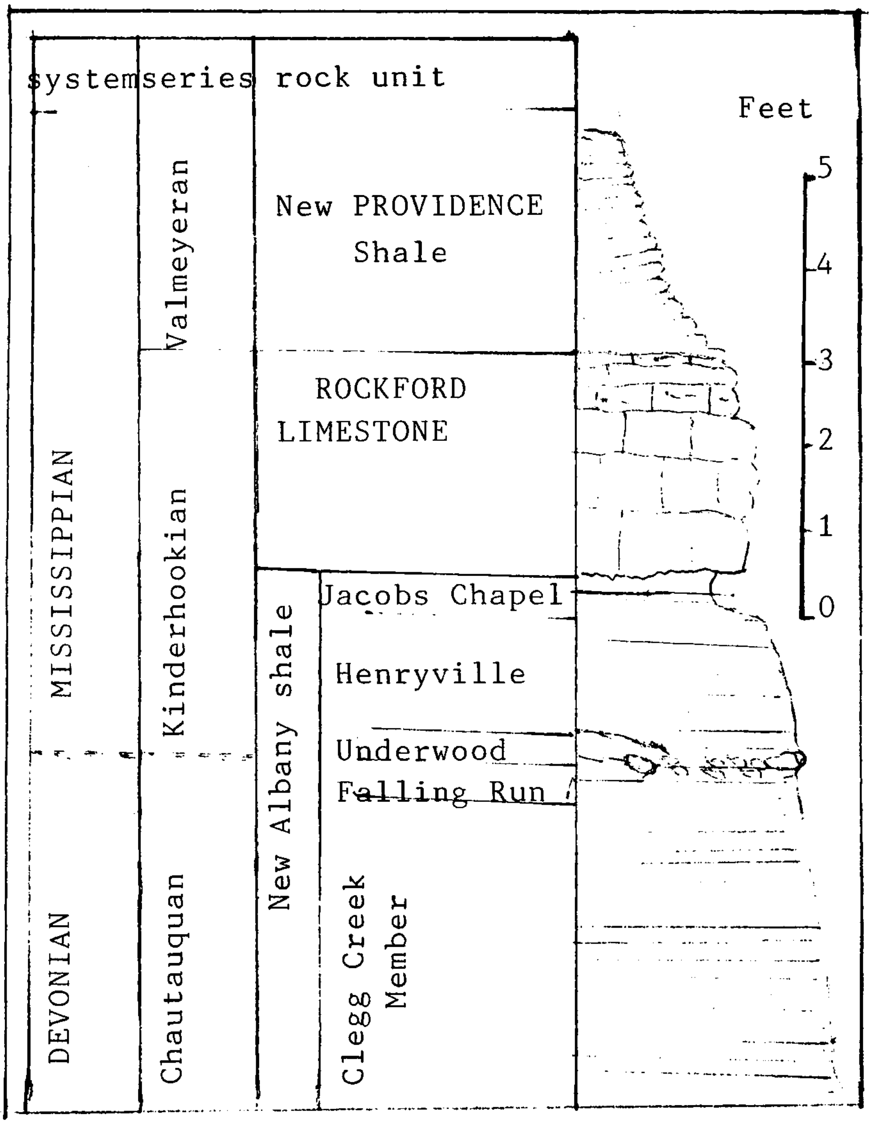


Diagram of Ceratites suture line,has secondary lobes.

AMMONITIC
suture

The suture line for the Jurassic and Cretaceous Ammonoids.

Black arrow on the left represents the median line of the venter. The line on the right shows the median line of the dorsum.



Columnar section showing stratigraphic position of the Rockford Ls. in southern Indiana.

EXTINCTION OF ANIMALS

Species, genera, families, and even orders and classes of the animal kingdom have become **EXTINCT** in the geological past.

AMMONIODEA
ARCHAEOCYATHIDS
BELEMNOIDS
BLASTOIDEA
CARPOIDEA
CYSTOIDEA
DENTROIDEA
DINOSAURS
EDRIOASTEROIDEA
EOCRINOIDEA
GRAPTOZOA
ICHTHYOSAUR
MOSASAURS
PARACRINOIDEA
PLESIOSAURS
PTEROSAURS
RUDIST CLAMS
STOMATOPOROIDS
TRILOBITA

On the Right Track:
The Relevance of Vertebrate Trace Fossils to Extinctions

Glen J. Kuban
P.O. Box 33232
North Royalton, OH 44133
Email: paleo@ix.netcom.com

Ichnology, the study of fossil tracks, burrows, eggs, and other "trace fossils," has experienced a major revival during the last 15 years. Although once regarded as minor curiosities, vertebrate footprints in particular have become increasingly appreciated as rich sources of information on the behaviors, locomotion, postures, foot anatomy, paleoenvironments, chronologies, and geographic distributions of many prehistoric animals (Lockley, 1991; Lockley and Gillette, 1989; Thulborn, 1990; Farlow, 1987; Kuban, 1994).

Although relatively little work has been done in the application of fossil tracks to questions about extinctions, there is great potential for future work in this area. One major advantage of working with footprints is that in most cases one can be sure the trackway is in its original position, and has not been "reworked" (redeposited from older or younger sediments). The same cannot be said for disarticulated teeth and bones, and even some trace fossils such as egg fragments, all of which can be readily transported and redeposited. Setting aside birds, all claims of post Cretaceous dinosaurs (Rigby, 1985, 1987; Rigby *et al*, 1987; Sloan *et al*, 1986) have been plagued by the possibility of reworking (Argast *et al*, 1987; Bryant *et al*, 1986; Behrensmeyer, 1982). However, even a single *in situ* dinosaur trackway younger than the K-T boundary would provide powerful evidence for Tertiary dinosaurs. As it is, footprints already provide evidence for dinosaurs closer to the K-T boundary than any other kind of evidence.

Horner and Lessem (1993) state that no dinosaur remains are found within about 3 meters of the iridium band taken to represent the K-T boundary in Montana. They call this the "three-meter" gap, and suggest that it represents perhaps 100,000 years. Some have interpreted this as support for the position that the Cretaceous extinction was a gradual rather than sudden event. However, the 3-meter gap does not exist if one includes footprints. The youngest-known dinosaur fossils so far are actually a set of hadrosaur tracks found by Lockley and Hunt (1995, p. 23) in a sandstone shelf only 37 cm (less than 15 inches) below the iridium layer near Ludlow, Colorado, in the Raton Formation. This discovery provides obvious proof that at least one group of dinosaurs was alive and well very near the end of the Cretaceous--and narrows the gap of "missing" dinosaur remains by an order of magnitude.

In fact, it may narrow the gap even more than that if the time frame rather than the sediment thickness is considered. The track bearing layers containing the hadrosaur tracks, which are rich in plant remains and thought to represent a coal swamp or peat bog environment. Based on sedimentation rates in similar environments today, Lockley and Hunt (1995) estimate the 37 cm may represent only a few thousand years or less. Additional hadrosaur tracks have also been found within the 3 meter gap, including a set 59 cm below the K-T boundary at the same site, and another Raton Formation Site about 12 miles south, which contains both hadrosaur and ceratopsian tracks within 1 or 2 meters of the K-T boundary (Lockley and Hunt, 1995).

It is exciting to contemplate the potential tracks have for further clarifying which dinosaurs survived until the close of the Cretaceous, and how sudden or gradual the decline was--not to mention the potential of confirming post-Cretaceous dinosaurs. Indeed, the problem with using body fossils only to study the timing of the K-T extinctions, is that isolated bones and teeth might have been reworked both below and above the boundary, possibly skewing any conclusions about the timing of the event or animals present. However with tracks, this problem is largely eliminated.

Tracks have also been useful in dating earlier Mesozoic events. As noted by Lockley and Hunt (1995), the track record shows a dramatic faunal change turnover at the Triassic-Jurassic boundary. Moreover, in many areas, and especially the east coast of the U.S., the diversity and abundance of dinosaur footprints and other vertebrate traces far exceeds that from body fossils (Weishampel and Young, 1996). Although much work needs to be done sorting out the great confusion of track names accumulated over the years, the potential for further clarifying the Triassic-Jurassic changes and dinosaur evolution in general is great.

Of course, work is also being done on the relevance of invertebrate traces to extinction events, such as Ekdale and Bromely (1984), and Wignall and Twitchett (1996), which help define the status of various invertebrate groups near extinctions boundaries, the environmental conditions associated with them, and perhaps even the cause of the extinction. Nevertheless, when it comes to vertebrates, dinosaurs clearly make the biggest impressions, and studies of their tracks should continue to elucidate the timing and nature of the K-T extinction and other great events in prehistory.

Acknowledgments

I thank James O. Farlow and Martin Lockley for helpful advice and references, and Ava and Michel Farivar, Gary R. Kuban, and Pat Newhauser for reviewing the manuscript.

References Cited

Behrensmeyer, A. K. 1982. Time resolution in fluvial vertebrate assemblages. *Paleobiology.* V. 8, p. 211-227.

Bryant, L. J., Clemens, W. A., and Hutchison, J. H. Cretaceous-Tertiary dinosaur extinction [letter]. *Science.* V. 234, p. 1172-1173

Ekdale, A. A., and R. G. Bromely, 1984. Sedimentology and ichnology of the Cretaceous-Tertiary boundary in Denmark: Implications for the causes of the terminal Cretaceous extinction. *Journal of Sedimentary Petrology*, V. 54, p. 681-703.

Farlow, J. O. 1987. *A Guide to Lower Cretaceous Dinosaur Footprints and Tracksites of the Paluxy River Valley, Somervell County, TX.* Baylor University, Waco, Texas.

Horner, J. and D. Lessem. 1993. *The Complete T. rex.* Simon & Shuster. New York.

Kuban, G. J. 1994. An Overview of Dinosaur Tracking. In: *MAPS Digest*, Expo XVI Edition, p. 197-208. Also see world wide web site at: http://members.aol.com/paluxy2/paluxy.htm

Lockley, M. G. 1991. *Tracking Dinosaurs.* Cambridge University Press. Cambridge, England.

Lockley, M. and D. Gillette, eds. 1989. *Dinosaur Tracks and Traces.* Cambridge University Press, Cambridge, England.

Lockley, M. and A. P. Hunt. 1995. *Dinosaur Tracks and other Fossil Footprints of the Western United States.* Columbia University Press. New York. p. 238-40.

Rigby, J. K., Jr. 1985. Paleocene dinosaurs: the reworked sample question. *Geological Society of America Abstracts with Programs*. V. 17, no. 4, p. 262.

Rigby, J. K., Jr. 1987. The last of the North American dinosaurs, in: *Dinosaurs Past and Present, Vol. II*. ed. by S. J. Czerkas and E. C. Olsen. Natural History Museum of Los Angeles County and University of Washington Press.

Rigby, K. J., Jr., K. R. Newman, J. Smith, and R. E. Sloan. 1987. Dinosaurs from the Paleocene Part of the Hell Creek Formation, McCone County, Montana. *Palaios* 2. p. 296-302.

Sloan, R. E. and L. Van Valen. 1965. Cretaceous mammals from Montana. *Science*. V. 148: 629-633.

Thulborn, T. 1990. *Dinosaur Tracks*. Chapman and Hall. London.

Weishampel, D. B. and L. Young. 1996. *Dinosaurs of the East Coast*. John Hopkins University Press. Baltimore.

Wignall, P. B. and R. J. Twitchett. 1996. Oceanic anoxia and the end of Permian mass extinction. *Science*. V. 272. p. 1155-1158.


THE YEAR OF EXTINCTIONS