GEOL 220T Spring 1989

Scientific Method and the Paradox of Controversy

Lesson 1 (group meeting): How are problems solved in Historical Geology?

Common Readings:

1. Bacon, F. 1627. New Atlantis (from selected works edited by A. Johnston, Francis Bacon), Schocken Books, New York, pp. 171-181.
2. Swift, J. 1726. Gulliver's Travels (from a recent pocketbook edition), pp. 135-144.
3. Rudwick, M.J.S. 1985. The Great Devonian Controversy. Univ. of Chicago Press. pp. 17-27.
4. Chamberlin, T.C. 1897. The method of multiple working hypotheses. Journal of Geology, v. 5, pp. 837-848. (on reserve shelf)

Questions

1. What is Bacon trying to show with his fable of "Solomon's House?"
2. Why, nearly a century later, does Swift poke fun at Bacon? What flaws exist in Baconian science?
3. How does the evolution of the London Geological Society as an arena of "gentlemanly debate" illustrate movement away from Baconian science to a model of progress through controversy?
4. By what means does Chamberlin attempt to lessen the propensity for conflict in the interpretation of historical geology? Does this view herald a return to Baconian concepts? How does Chamberlin see the basic fabric of geology?

Assignment:

1. Do all the readings.
2. Prepare an outline for an essay exploring the three sorts of "scientific method" represented by the authors above (do not actually write the essay, but produce a real outline and be ready to discuss the merits and meanings of different methodologies.
3. Try to keep these models in mind as we explore the current issues in historical geology during the tutorials.

Remember that our goal is not necessarily to prove who may be right or wrong with respect to a particular issue, but rather to try and understand how science is done.

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Lesson 2 (1st tutorial): What's wrong with uniformitarianism?

Common readings:

1. Shea, J.H. 1982. Twelve fallacies of uniformitarianism. Geology 10: 455-460
2. Gould, S.J. 1984. Toward the vindication of punctuational change. In Berggren, W.A. & Van Couvering, J.A. (eds.), Catastrophies and Earth History. Princeton Univ. Press, Princeton N.J. pp. 9-33.
3. Zenger, D.H. 1986. Lyell and episodicity. Jour. Geol. Education 34:10-13.
4. Dott, R.H., Jr. 1983. Episodic sedimentation – How normal is average? How rare is rare? Does it matter? Jour. Sedimentary Petrology 53: 5-23.

Questions:

1. According to Shea, why should the term "uniformitarianism" be abandoned? Without reciting the whole litany of drawbacks, what are the most important charges? Does he have any vested interests?
2. What historical overtones does Gould allude to? What are his vested interests?
3. How does Zenger attempt to rescue uniformitarianism? Are there any geological processes which occur at a gradual rate? Is this whole issue a matter of semantics? If so, how can it be resolved? What, if anything, is really at stake?
4. What is the significance of cyclic as opposed to nonperiodic episodes of sedimentation? What viewpoint does Dott bring to the issue?

Assignment:

What is uniformitarianism? Is it a worn-out concept or does Lyell have something to say to us? Is this concept compatible with episodic change? What kinds of geological events are gradual and what kinds are not? Are people like Gould reinventing the wheel or is uniformitarianism so weighted by historical baggage that the modern geologist is better off without it?

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Lesson 3 (2nd tutorial): What's wrong with catastrophism?

Common readings:

1. Kuenen, Ph.H. and Migliorini, C.I. 1950. Turbidity currents as a cause of graded bedding. Jour. Geol. 58: 91-127.
2. Bramlette, M.N. and Bradley, W.H. 1940. Geology and biology of North Atlantic deep-sea cores, Part I: U.S. Geol. Survey Prof. Papers 196-A, pp. 15-16.
3. Pettijohn, F.J. 1950. Turbidity currents and greywackes – A discussion. Jour. Geol. 58: 169-170.
4. Baker, V.R. 1978. The Spokane flood controversy. In Baker, V.R. & Nummendal, D. (eds.) The Channeled Scabland. Planetary Geol. Prog. NASA, pp. 3-15.

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5. Baker, V.R. 1981. Catastrophic flooding – The origin of the Channeled Scabland. Benchmark Papers in Geology /55. Dowden, Huchison & Ross, Inc., Stroudsberg, Penn. 359 p. [collection of original articles by Bretz and his opponents].
6. Waitt, R.B., Jr. 1985. Case for periodic, colossal jokulhlaups from Pleistocene glacial Lake Missoula. Geol. Soc. Amer. Bull. 96: 1271-1286.

These are very good sources for additional but not required reading.

Questions:

1. This set of readings involves several geological terms which require mastery. What is a: turbidity current, greywacke, a channeled scabland, a jokulhlaup?
2. What did Kuenen and Migliorini manage to do in 1950 that Bramlette and Bradley did not already say in 1940?
3. What important connection did Pettijohn immediately make after reading Kuenen & Migliorini?
4. What is at the heart of the Channeled Scabland Controversy? How does Waitt turn the argument on its head?
5. Why should Bretz' concept of a subaerial catastrophy meet with such vehement opposition when Kuenen & Migliorini's concept of submarine catastrophy was so readily embraced?

Assignment:

Geologists are not a monolithic group of scientists; they work in many subdisciplines. Why should submarine geologists have an easier time swallowing the notion of cataclysmic events than geomorphologists (geologists who study landforms)? Were geologists different in the 1930s (when Bretz and company did their work) as opposed to the early 1950s (When Kuenen and company did their work)? Is there any difference in the inherent quality of evidence, or is there simply a particular threshold of evidence that needs to be passed before any concept is acceptable? How is uniformism invoked when cataclysmic events are shown to have been episodic?

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Lesson 4 (3rd tutorial): Gradualism vs. punctualism in evolutionary rates

Common readings:

1. Scully, E.P. 1987. Current issues in evolutionary paleontology. Jour. Geol. Education 35: 80-85. [This is a particularly good, brief review with a thorough bibliography; the reference to Eldredge and Gould (1972) is a classic you may want to consider for further explanation].
2. Eldredge, N. 1985. Time Frames. [Chapter 3: At sea in the American Midwest]. Simon and Schuster, New York, pp. 57-91.
3. Sheldon, R.P. 1987. Parallel gradualistic evolution of Ordovician trilobites. Nature 330: 561-563. [a one-page essay by John Maynard Smith from the same issue of Nature is appended to your copy].
4. Wei, K.-Y. and Kennett, J.P. 1988. Phyletic gradualism and punctuated equilibrium in the late Neogene planktonic foraminiferal clade Globoconella. Paleobiology. 14: 345-363.

Questions:

1. What is the historical background (according to Scully) of the debate between phyletic gradualism and punctuated equilibria? How does this debate relate to the issues of uniformism and catastrophism already considered in previous tutorials?
2. The original example of "punctuated equilibria" in the fossil record was based on trilobite evidence collected by Niles Eldredge. In Time Frames, he describes how he developed the idea. What kind of approach to research (referring to our discussion in the group meeting) did Eldredge follow? What do species boundaries in lines of descent mean to him?
3. A recent example of gradualism by Sheldon (1987) also focuses on trilobite evolution. What sort of approach to research does Sheldon advocate? What do species boundaries (or potential boundaries) in lines of descent mean to him?
4. The final reading from Wei & Kennett (1988) is based on fossils representing single-cell, shelled "protozoans" called foraminifera. What kind of conclusion do they arrive at regarding the pros and cons of the two evolutionary models? In particular, what advantage over Eldredge or Sheldon do Wei & Kennett make use of through their research on micro-fossils? How does their view of species boundaries compare with those of Eldredge and Sheldon?

Assignment:

The key concepts you should attempt to explore revolve around the relationships of phyletic gradualism and punctualism to uniformism and catastrophism, -to the scientific methodologies followed by the various paleontologists, and –to their differing view on the drawing of species boundaries in lines of descent. As always, you may restrict your analysis to the references supplied in the syllabus, or you may consult any additional references in the bibliographies contained.

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Lesson 5 (4th tutorial): Controversial taxonomies in invertebrate paleontology

Common readings:

1. Scrutton, C.T. 1987. A review of Favosited affinities. Paleontology. 30: 485-492
2. Copper, P. 1985. Fossilized polyps in 430-Myr-old Favosites corals. Nature. 316:142-144
3. Briggs, D.E.G., Clarkson, E. and Aldridge, R.J. 1983 The conodont animal. Lethaia. 16:1-14
4. Runnegar, B. 1982. Oxygen requirements, biology and phylogenetic significance of the late Precambrian worm Dickinsonia, and the evolution of the burrowing habit Alcheringa. 6: 223-239
5. Seilacher, A. 1984. Late Precambrian and early Cambrian metazoa: Preservational or real extinctions? In Holland, H.D. and Trendall, A. F. (eds.). Patterns in Change in Earth Evolution. Springer-Verlag, Berlin, pp. 159-168.

Some additional, but not required references on the reading shelf:

6. Sweet, W.C. 1988. The Conodonta. [Chapter 8: The Phylum Conodonta]. Clarendon Press, Oxford, pp. 107-184.
7. Gould, S.J. 1984 . The Ediacaran experiment. Natural History. February, pp. 14-23.

Questions:

1. Ultimately, the quality of data decides whether the taxonomic placement of extinct organisms is more-or-less correct. Scrutton uses several pages to review the pros and cons of a sponge or coral assignment for Favosites. What is the quality of Copper's data on this issue?
2. Condonts are extinct organisms, the remains of which are very useful in biostratigraphic correlation of rock layers of Cambrian to Triassic age. Despite their great utility, very little was known about their possible taxonomic affinities until the work by Briggs et al (1983). Does it make a difference whether we ever really know the affinities of this animal? Keeping in mind our discussion during the 1st course meeting, what kind of approach to science to you think this team followed?
3. The oldest metazoan (macroscopic) organisms yet known belong the famous Ediacaran fauna with exclusively soft-tissue body structures (over 600 million years old). The papers by Runnegar (an Australian paleontologist) and Seilacher (a German paleontologist) are diametrically opposed in their interpretations. What old issues are at stake here? The essay by Gould may help to better clarify the two outlooks.

Assignment:

This set of papers does not revolve around a single controversy. Their only shared theme is the question of how extinct animals should be taxonomically classified. In this case, all the animals involved traditionally have been classified as invertebrates. As vertebrate animals ourselves, we often tend to "look down" on the invertebrates as something less interesting. This tutorial is intended to show you that it's fun to think about invertebrate fossils. Try to focus on the questions of quality "facts" and their interplay with something which is totally a human fabrication [taxonomy, - or the classification of plants and animals].

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Lesson 6 (5th tutorial): Controversial physiographies in vertebrate paleontology

Common readings:

1. Bakker, R.T. 1986 The Dinosaur Heresies. Chapt. 10: The Teutonic Diplodocus: A lesson in gait and carriage. William Morrow & Co., Inc., New York, pp. 201-225
2. Horner, J.R. and Makela, R. 1979 Nest of juveniles provides evidence of family structure among dinosaurs. Nature 282: 296-298
3. Horner, J.R. & Weishampel, D.B. 1988 A comparative embryological study of two ornithischian dinosaurs. Nature 332: 256-257.
4. Brouwers, E.M. et al. 1987. Dinosaurs on the North Slope, Alaska: High latitude, latest Cretacous environments. Science 237:1608-1610
5. Rich, P.V. et al. 1988. Evidence for low temperatures and biological diversity in Cretaceous high latitudes of Australia. Science 242: 1403-1406

Questions:

1. Following Bakker's historical treatment, what kind of evidence did the American paleontologists working for Andrew Carnegie develop to support an upright posture for Diplodocus? Why did the German paleontologists object? Why did this issue subsequently fade away only to reappear more recently?
2. How are the two papers with Horner as senior author related? In particular, what is significant about the presence of absence of well-developed condyles at the tips of the femur bones in baby dinosaurs? In contrast, what point does Bakker (p.218) make about the retention of such cartilage in the joints of adult dinosaurs? What is the evidence for nesting behavior in some dinosaurs and how does this relate to the central theme issue of endothermy?
3. How do the related papers by Brouwers et al (1987) and Rich et al (1988) challenge the hypothesis that dinosaurian extinction was brought about a short period of global darkness and low temperature caused by bolide impact? Again, what is the link of endothermy.

Assignment:

A popular 19th century concept closely related to gradualism is the notion of "progression of types" in the evolution of major animal groups. In this respect, what is upsetting about evidence for dinosaur endothermy? Might Gould regard recent debates on this issue as an attack on substantice uniformitarianism? On the other hand, how do the various authors (of the assigned readings) employ methodological uniformitarianism?

The Williams College geologish Ebenezer Emmons played an interesting role in the mid-19th century debate over the question of progressive types. In so doing, Emmons won the support of Charles Lyell as a strict uniformitarian. Ask for additional references if you want to pursue this footnote in the history of geology.

Ironically, the latest geographic data regarding dinosaur endothermy flies in the face of currently popular ideas of catastrophic extinction. Have fun.

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Lesson 7 (6th tutorial): Clash of the fixists and drifters

Common readings:

1. Wood, R.M. 1985 The Dark Side of the Earth. Chapt. 4; Coming apart at the seams. Allen and Unwin, London, pp 61-87
2. Wood, R.M. 1985 The Dark Side of the Earth. Chapt. 6: A naval engagement. Allen and Unwin, London, pp. 122-154

Questions:

1. Chapter 4 of Wood (1985) covers the time period from about 1900-1930, dealing primarily with Alfred Wegener and his theory of "continental drift." How did this theory evolve? What was the cause of its undoing?
2. Chapter 6 of Wood (1985) covers the time period from about 1930-1965, dealing with several interesting personalities and the triumph of the theory of "plate tectonics." If the data implicit in continental drift is only a subset of the data embodied by plate tectonics, what extra features account for the success of the later theory?

Assignnment:

Most of the issues dealt with so far in this course involve on-going disputes in historical geology. The 1st session after spring break will focus on a major issue which is now generally thought to have been settled. The clash between the "fixists" and the "drifters" was initiated around 1910 to 1915 and went through various modes until the scales of respectable science tipped in favor of plate tectonics during the mid-1960s. Try to explore the personalities, institutions and conventions (i.e. the role of scientific press, for example) which fomented this controversy. Why did the concept of continental drift fail only to be successfully resurrected under the guise of plate tectonics?

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Lesson 8 (7th tutorial): The stratigraphy of sea-level events: gradualism vs. punctualism

Common readings:

1. Anderson, E.J., Goodwin, P.W., and Sobieski, T.H. 1984. Episodic accumulation and the origin of formation boundaries in the Helderberg Group of New York State. Geology 12: 120-123
2. Kradyna, J.W. and Mehrtens, C.J. 1984. Forum: Comment & reply. Geology 12: 637-638
3. Kerr, R.A. 1987. Redefining and defending the Vail sea level curve. Science 235: 1141-1142
4. Haq, B.U., Hardenbol, J., and Vail, P.R 1987. Chronology of fluctuating sea levels since the Triassic. Science 235: 1156-1167
5. Letters by readers of Science. 1988. Technical comments. Science 241: 596-602

Questions:

1. What is a PAC, according to Anderson et al (1984)? How do their small-scale observations on the Devonia formations of New York relate to our previous discussions of abrupt events in geomorphology, marine geology and paleontology?
2. What is the main objection against PACs voiced by Kradyna & Mehrtens (1984)? To understand their concerns, you may wish to look up the definition of "facies" in a geology dictionary.
3. Kerr (1987) gives a brief history of the Vail sea-level curves and outlines the importance of the revisions in the Haq et al (1987) paper. What was one of the major sources of criticism prior to 1987?
4. Why in the diagrams on page 11612, 1163 and 1165 (Haq et al., 1987) is there a difference between the punctuated curves representing "coastal onlap" and smooth curves representing "eustasy?" How are these differences reconciled? Does this signify a new stage in the development of the Vail sea-level curves.
5. What kind of objection to Haq et al. (1987) do the readers of Science offer in the "Technical Comments" published the following year? How do Haq and his colleagues respond? Can we detect anything about the give and play of science from these "letters to the editor?"

Assignment:

The original research articles by Anderson et al. (1984) and Haq et al (1987) operate on two very different levels of observation both in terms of vertical and horizontal scale. Make sure you understand this, as well as the very different ways in which the two sets of authors explain abrupt boundaries in the stratigraphic record.

What (by now) common themes do we see in the criticisms of these authors expressed by other geologists? How do the principles of gradualism as opposed to punctualism fare in this particular debate?

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Lesson 9 (8th tutorial): Finding the cause of the terminal Cretaceous extinction event

Common readings:

1. McCartney, K. and Loper, D.E. 1989. Emergence of a rival paradigm to account for the Cretaceous/Tertiary event. Jour. Geol. Education 37:36-48. [this is an excellent review article treating the entire debate since its inception with the 1980 article in Science by Alvarez et al. – for the purpose of this lesson, however, ignore the material on episodicity, which we will take up in greater detail last week]
2. Alvarez, W., Kaufmann, E.G., Surlyk, F., Alvarez, L.W., Asarao, F., and Michael, H.V. 1984. Impact theory of mass extinctions and the invertebrate fossil record. Science 223: 1135-1141
3. Officer, C.B. and Drake, C.L. 1985. Terminal Cretaceous environmental events. Science 227: 1161-1167
4. Bourgeois, J., Hansen, T.H., Wiberg, P.L., and Kaufmann, E.G. 1988 A tsunami deposit at the Cretaceous-Tertiary boundary in Texas. Science 241: 567-570
5. Wolbach, W.S., Gilmour, I., Anders, E., Orth, C.J., and Brooks, R.R., 1988. Global fire at the Cretaceous-Tertiary boundary. Nature 334: 665-669

Questions:

1. What are the bare facts of the terminal Cretaceous event? In other words, what sorts of data are agreed on by all sides in this dispute over the cause of the event?
2. Alvarez and his colleagues first published their theory of an extra-terrestrial cause for the terminal Cretaceous extinctions in 1980 and they have been defending their concept against critics ever since. This exercise picks up with the first major response by Alvarex et al. (1984). How did they strengthen (or weaken) their model with the 1984 paper?
3. What is the major point of the succeeding paper by Officer & Drake (1985)? How was their interpretation been strengthened since 1985, according to McCartney and Loper (1989)?
4. Although McCartner & Loper (1989) provide the most recent summary of this debate, their paper probably took 4-6 months to be reviewed, accepted by an editor and published. In the meanwhile, much additional data of possible significance has been generated by other geologists. What standpoint do Bougeois et al. (1988) and Wolbach et al. (1988) take on the issue. Does their evidence destroy the McCartney & Loper vision of the new paradigm? Or, may their data be "reprogrammed" to fit the new paradigm?

Assignment:

The nature of the Cretaceous-Tertiary transition may be "one of the most controversial scientific topic of this decade (McCartney & Loper, 1989, p. 36). Try to separate ouot the hard data of the case from all the scientific sensationalism. What is remarkable about the boundary layer separating the Upper Cretaceous and Lower Tertiary strata? How many different ways may the emplacement of this boundary layer be explained? What range of "punctuationalism" is represented by the available models? To what degree, if any, is uniformitarianism challenged?

We have observed previously in this course, that polarized issues in geology are not beyond some temporary resolution (i.e. the debate between the fixists and drifters, or between the gradualists and punctuationalists in the paleontological community). What will it take to settle this debate over the cause of the end Cretaceous event?

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Lesson 10 (9th tutorial): Random and periodic mass extinctions?

Common readings:

1. Raup, D.M. 1986 The Nemesis Affair. Chapt. 7: Enter periodic extinction. W.W. Norton and Co., New York, pp. 107-129
2. House, M.H. 1987. Essay review: Geological Rhythms, cycles and other revolutions. Geol. Magazine 124: 273-276
3. Noma, E. and Glass, A. 1987 Mass extinction patterns: result of chance. Geol Magazine 124: 319-322
4. Fox, W.T. 1987 Harmonic analysis of periodic extinctions. Paleobiology 13: 257-271

Supplementary texts (for extra but not required reading)

5. Septkoski, Jr. J.J. 1989 Periodicity in extinction and the problem of catastrophism in the history of life. Jour. Geol. Society of London 146: 7-19
6. Hoffman, A. 1989 Mass extinctions: the view of a skeptic. Jour. Geol. Society of London 146: 21-35

Questions:

1. Raup's (1986) account gives an insider's view of how the 26 m.y. periodic mass extinction theory was formulated and spread. Much earlier, Fischer and Arthur (1977) proposed a 32 m.y. periodic extinction theory. Why was Raup and Sepkoski's work so successful in attracting attention, while Fischer and Arthur were virtually ignored?
2. What does House (1987) have against cyclicity, in general, and against the Raup-Sepkoski theory, in particular.
3. In articles published almost simultaneously, Noma and Glass (1987) and Fox (1987) applied statistical theory to an analysis of mass extinctions in the geologic record – but with entirely contradictory results. How can this happen? Can you identify any critical differences in the assumptions these authors start out with?
4. What key criticism(s) of House (1987) are left unanswered by Fox (1987), assuming his statistics are right?

Assignment:

House (1987, p. 274) proclaims that: "One of the enlivening features of the American way of life is the role of novelty, fashion and the gimmick." Is this really true of our science as well? Is American science tainted? Or is House just a bi jealous? Of what? The 26 m.y periodic mass extinction theory: is it the ultimate in catastrophism – is it just an extreme case of uniformism? Or is it a gimmick? What are the strengths and weaknesses of this controversy?

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Lesson 11 (10th tutorial): Atmospheric evolution: steady-state as opposed to gradual or episodic change?

Common readings:

1. Cloud, P. 1973 Paleoecological significance of the banded iron-formation. Economic Geology 68: 1135-1143
2. Berner, R.A. and Landis, G.P. 1988 Gas bubbles in fossil amber as possible indicators of the major gas composition of ancient air. Science 239: 1406-1409
3. Reader's technical comments. 1988 Is the air in amber ancient? Science 241: 717-241

Questions:

1. What exactly are BIFs and what do they tell us about the early Precambrian atmosphere, according to Cloud (1973)? Why did the deposition of BIFs cease? Does the concept of uniformism fail the Precambrian world?
2. What is amber and how does it form? What sort of laboratory technique is employed by Berner and Landis (1988) to get a handle on the composition of the late Mesozoic and early Cenozoic atmospheres? What rather startling results did they derive regarding oxygen levels? What assumptions have to be made for these results to be credible?
3. Assuming Berner and Landi (1988) are approximately correct, what does the Gaia Hypothesis have to do with the notion of an evolving atmosphere (see letter by Chave & Smith, p. 710-720)? What relationship might be drawn with the Cretaceous-Tertiary global wild fires we previously read about?
4. Berner and Landis (1988) could also be very wrong in their laboratory estimates. What specific criticisms are leveled by some of the "technical comments?"

Assignment:

In his conception of uniformitariansim, Charles Lyell originally envisioned a perfectly steady-state Earth. Regarding the Earth's atmosphere, how far back in time may we assume such a steady-state system. Who is more convincing in their arguments for atmospheric evolution, Cloud (1973) or Berner and Landis (1988)? What are the theoretical benefits (scientifically speaking) of endorsing a modulating atmosphere – particularly one with "abnormally high" Cretaceous levels of 0_2? What is the margin for potential error in the associated field or lab calculations? What risk is there in such high visibility studies?