Notes from the Panorama of Science

Uniformity and Uniformitarian Concepts in Sedimentology

In discussions with some contemporary geologists, it has become apparent that Lyellian Uniformitarianism is regarded as a relic of the past. “Modern-day geologists have moved on,” they say. “We are now as open to catastrophism as anyone, but we need to be persuaded by the evidence.” However, despite these affirmations, it is also apparent to me that many of these geologists continue to think in uniformitarian ways. It appears to be very difficult for them to get out of the deep conceptual ruts created by Lyellian geology!

One of the ways the uniformitarian mindset is perpetuated involves an appeal to the laws of physics. “You cannot escape the fact that this is how nature behaves!” A popular specific example involves Stokes’ Law, which describes the way a particle in suspension moves through a fluid under the influence of gravity. By putting appropriate figures into the equation, it is a simple matter to show that some fine-grained sediments must have taken a long time to settle out of suspension. “For these sediments, catastrophism has to be ruled out of consideration—QED!” To the unwary, this argument sounds compelling, for who dares to challenge tried-and-tested laws of physics?

The root problem to address here is reductionism. The argument is made by people who think they understand the building blocks of our world and the way they interact. This allows them to build up a picture of the whole that they consider to be complete (this thinking, for example, lies behind the elusive “Theory of Everything”). There are at least two fallacies: first that we understand all the building blocks and second, that we understand the way they interact! In what follows, we shall consider three types of sediment that have all been claimed to accumulate slowly and elaborate on the two fallacies. The sediments are volcanic ash deposits, diatomite and chalk.

Volcanic ash from a recent eruption from Mount Pinatubo

In 1991, Mount Pinatubo in the Philippines erupted and large quantities of volcanic ash fell into the sea. Application of Stokes’ Law suggested a timescale for settling of three months, but an ash layer formed on the seabed within three days (Wiesner et al., 1995). Clearly, something was missing from the analysis. It is not that Stokes’ Law is wrong: no one thinks that the laws of physics changed in any way. The problem was in the model of deposition. It was deficient because the ash particles did not behave as independent particles in suspension (as they would have to do if they were to be described by Stokes’ Law). Alternative theories to explain the data were considered by Manville and Wilson (2004). Their work was supported by laboratory experimental simulations and the conclusion they reached was that the ash fall on the ocean surface produced density currents that flowed vertically to the sea floor. In other words, the ash fall created a fluid of higher density than seawater and that fluid descended coherently through the water column. (These authors also found evidence for rapid diagenetic processes, but that does not concern us here because our focus is on deposition.)

This is an example that concerns the *interactions* of particles in suspension. Instead of behaving independently, a density current formed that moved “two to three orders of magnitude greater than expected” (Wiesner et al., 1995, p. 887).

Diatoms from the Eocene of Chile

Diatoms are the siliceous bodies of unicellular algae living in oceanic surface waters. When they die, the frustules (the siliceous skeletons) descend to the ocean floor and become part of the accumulating sediment. Diatom sizes are commonly in the range of 10–200 μm. According to Stokes’ Law, individual cells with these sizes require 1 week to 2 years to be deposited. In modern ocean basins, diatom frustule and mud accumulation rates are low (one study off the coast of California reported a rate of 40–73 cm of sediment in a thousand years). Geologists refer to “diatomaceous ooze” when the proportion of diatoms becomes significant. Diatomaceous deposits are of commercial interest because they are made up of relatively pure silica in a hydrated form that favours chemical processing. Mineable deposits are typically inferred to have formed over thousands of years.

By analogy with the volcanic ash example, is it possible for diatoms to form quickly and to be deposited quickly? Are there modes of deposition other than the “independent particles in suspension” that is described by Stokes’ Law? The answer to this is undoubtedly “yes.” For example, it is known that many planktonic diatoms should not be regarded as individual cells because they form multicellular chains. These can be several mm in length.

However, the major evidence for more rapid modes of deposition comes from the presence of fossil vertebrates in some diatomite beds. The most striking case concerns fossilised baleen whales in diatomaceous rocks in the Cerro Bianco region of Peru. The lower part of the Pisco Formation is mostly sandstone with some diatomaceous units. The upper part, about 80 m thick, has diatomaceous units plus mudstones with volcanic ash. Within this unit are fossil baleen whales, 5 to 13 m long, many of which are extremely well preserved. In recently reported research (Brand et al., 2004), 346 whales were studied in a 1.5 km^2 area of exposed ground. These fossils occasionally preserved soft tissues, including baleen. The only other common fossils are sharks' teeth, but the formation has also yielded fish, turtles, seals, porpoises, penguins and even ground sloths.

Brand et al. considered three mechanisms of deposition: (1) anoxia in stagnant water, preserving the whales while sediment accumulated slowly, (2) diatom mats were rafted in to cover the bodies and inhibit scavengers, and (3) rapid burial by diatomaceous sediment. Their paper discusses relevant observations, rejects options 1 and 2, and concludes that option 3 is supported by the evidence.

"This necessity of rapid burial indicates that, at times in the past, diatom accumulation rates were much higher than those typical in modern oceans" (Brand et al., 2004, p.168). The mechanisms suggested are abundant diatom blooms offshore (i.e. an "explosion" of the diatom population as a result of abundant food supply and favorable conditions for reproduction) combined with currents bringing frustules to a region of accumulation. This research, therefore, documents a convincing case of these sediments accumulating over much shorter timescales and it succeeds in injecting a catastrophist alternative to what has hitherto been a uniformitarian stronghold. The "Stokes' Law sedimentation" of particles has to be perceived as one extreme of a spectrum of depositional modes.

This case concerns the *building blocks* of diatomite formation. Although diatom blooms are known today, we have no records of events that match up to the Cerro Bianco deposits. Processes in the past have gone well beyond present-day experience. The presence of volcanic ash in these deposits may be significant—as is discussed below.

Chalk from the Cretaceous Period

The most challenging case involving the deposition of small particles concerns chalk. This sediment is made up of the calcareous residues of certain algae known as Coccolithophores. The hard parts are called coccoliths, and their effective settling diameter is in the range 2 to 12 µm. These structures disaggregate to produce fragments in the range 1 to 4 µm. Since the wavelength of red light is about 0.7 µm, it was not possible to resolve the structure of the chalk until the advent of scanning electron microscopes. The larger particles require at least a year to descend to the sea floor, but disaggregated particles might take over 100 years! According to some estimates, 1 m of chalk represents about 100,000 years of time. In the modern oceans, coccolithophores are found in nutrient-poor waters and the coccoliths are always mixed with other materials in the sea-floor sediments. Deep sea chalk oozes from the Atlantic have a coccolith content (by weight) of 5–33%, and from the Indian Ocean 4–71% (Jeans and Rawson, 1980).

All the more surprising, then, to find chalk in abundance during the Upper Cretaceous and also represented in some Tertiary strata. This means that in the past, there were large areas of sea-covered continent, dominated by chalk-producing algae with relatively minor inputs of other sedimentary material. At best, with such slow rates of dropping out of suspension, we should expect to find only chalk oozes. Nevertheless, many of the chalk deposits are extraordinarily pure and very thick (about 350 m in southern England, and in the US the Niobrara Formation has a chalk member that averages about 180 m). Many have concluded that these chalk deposits must have been formed in ways that are unrepresented by modern-day processes: "no exact analogue of Cretaceous chalk can yet be quoted" (Jeans and Rawson, 1980, p. 92). Further information on the unusual characteristics of chalk strata are found in Tyler (1996).

Even conventional geology needs to find ways of depositing chalk faster than that allowed by Stokes' Law. One mechanism favoured by some is that coccoliths have typically been ingested by other organisms and excreted as coarser particles. These coarser aggregations fall out of suspension relatively quickly. This explanation has the merit of explaining significant differences in the textures of certain chalk sediments.

Other avenues of thought can be explored, of course. There is the possibility of forming algal blooms, with greatly increased rates of coccolith formation. The conditions for sustained explosive growth have yet to be identified in detail, but the basic idea has been discussed by Roth (1985) and developed by others.

It has been known for some time that iron can seed algal blooms, but experiments in the oceans have not been easy to interpret. Recent work with iron seeding has indicated that the mere presence of iron is not enough—it must be in a form that organisms can actually use. Two storms carrying iron-rich dust from the Gobi Desert into the Pacific Ocean have provided important insights into some relevant processes. Meskhidze et al (2005) provide the documentation.

As the storms passed over China, they picked up sulphur dioxide pollutants. It appears that a relatively high level of sulphur dioxide is able to convert the iron to a more soluble form that phytoplankton can use. The first storm resulted in an increase in phytoplankton but the second did not. The latter had a significant amount of carbonate dust to neutralize the SO_2.

One of the benefits of abandoning uniformitarian thinking is that previously unconnected data can be integrated in remarkable ways. This relates to the "interaction" weakness of uniformitarianism. It is well known that volcanic activity emits iron-rich dust together with large quantities of carbon dioxide and sulphur dioxide. Indeed, this phenomenon has led to people challenging Diluvialists about the extremely toxic environments that must have occurred during the catastrophism of the Flood and its after-effects. However, it now emerges that there are feedback mechanisms. Volcanism can boost phytoplankton growth (algal blooms) by introducing iron-rich dust and sulphur dioxide to ocean waters, increase the uptake of CO_2 (during photosynthesis) and generate lots of oxygen. Here is a feedback mechanism to help keep our planet in a fit state for life during any time of global instability involving volcanism.

The above scenario involves algal blooms in abundance. What is the situation with coccolith-producing algae? Coccolithophores have been described as among the fastest growing planktonic algae, yet unlike other most other photosynthetic plankton they do not appear to respond to fertilization by nitrate, phosphate, or iron. How then can these organisms be stimulated to bloom?

A significant breakthrough in understanding the environmental factors promoting chalk production has come from Stanley et al. (2005). These authors noted that low Mg/Ca ratios and high Ca concentrations characterized Cretaceous seawater. Also, that Paleocene seawater had Mg and Ca concentrations close to Cretaceous levels. Modern seawater has a high Mg/Ca ratio and about half the Cretaceous Ca concentration. The authors' hypothesis was that seawater concentrations were significant and they devised a set of experiments to test this out.

The authors were aware of nearly 300 coccolithophore species, mostly living in low abundance in nutrient-deficient subtropical/tropical gyres of the ocean. Three species were chosen for experimentation, and all responded strongly to Cretaceous seawater. One doubled its population growth, and the others had "exponential growth rates three to four times as high in Cretaceous seawater as in modern seawater" (Stanley et al., 2005, p. 595). One species changed the character of its coccolith generation: it "secreted larger and more heavily constructed coccoliths in Cretaceous seawater."

Stanley et al. (2005) suggest that modern-day coccolithophores are living in what amounts to a refugium. They do not thrive in high-Mg water. The factors affecting blooming still need attention, but this paper takes us a great deal further in explaining why Chalk is primarily a Late Cretaceous phenomenon, why modern-day coccolithophores do not show any signs of generating significant thicknesses of chalk, and in showing that, when conditions are right, these little organisms can multiply fast.

As far as chalk is concerned, would blooms have resulted in density currents? Would they lead to the aggregation of coccoliths? How would coccolith falls from blooms have affected the unique ecosystems that appear to have lived on the chalk sea floor? Although the answers to these questions are not yet clear, there must be mechanisms, because there is enough evidence for suspension settling by Stokes' Law to be ruled out as an option.

Conclusion

These issues help to illuminate the problems of uniformitarianism. It is not that uniformitarians are not prepared to accept evidences of catastrophism in the geological past. Rather, it is that uniformitarians have a very narrow perspective on geological phenomenon. They prefer to work with modern analogues and physical laws without testing "goodness of fit" and without exploring alternative hypotheses that allow equally good or improved correspondence between observation and theory. In the above three cases of sedimentation of fine particles, uniformitarianism has failed because of an inadequate understanding of the "building blocks" and their interactions. As far as I can see from research being published, significant advances are only coming when researchers are prepared to step outside the mould and question received wisdom.

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Spur and Groove Coral Reef Morphology

Introduction

Numerous patch reefs occur along the Florida Keys Coral Reef Tract. They are composed of a variety of soft and hard coral-producing organisms, with many exhibiting a similar geomorphic structure identified as spur and groove morphology. This hard coral framework has also been reported at reefs around the world. Even some "prehistoric" reefs appear to exhibit this morphology. Spur and groove morphology at the Florida Keys Coral Reef Tract demonstrates intelligence in its design and a preferred end state for the growth and development of a healthy Elkhorn coral-dominated (i.e., *Acropora palmata*) patch reef.

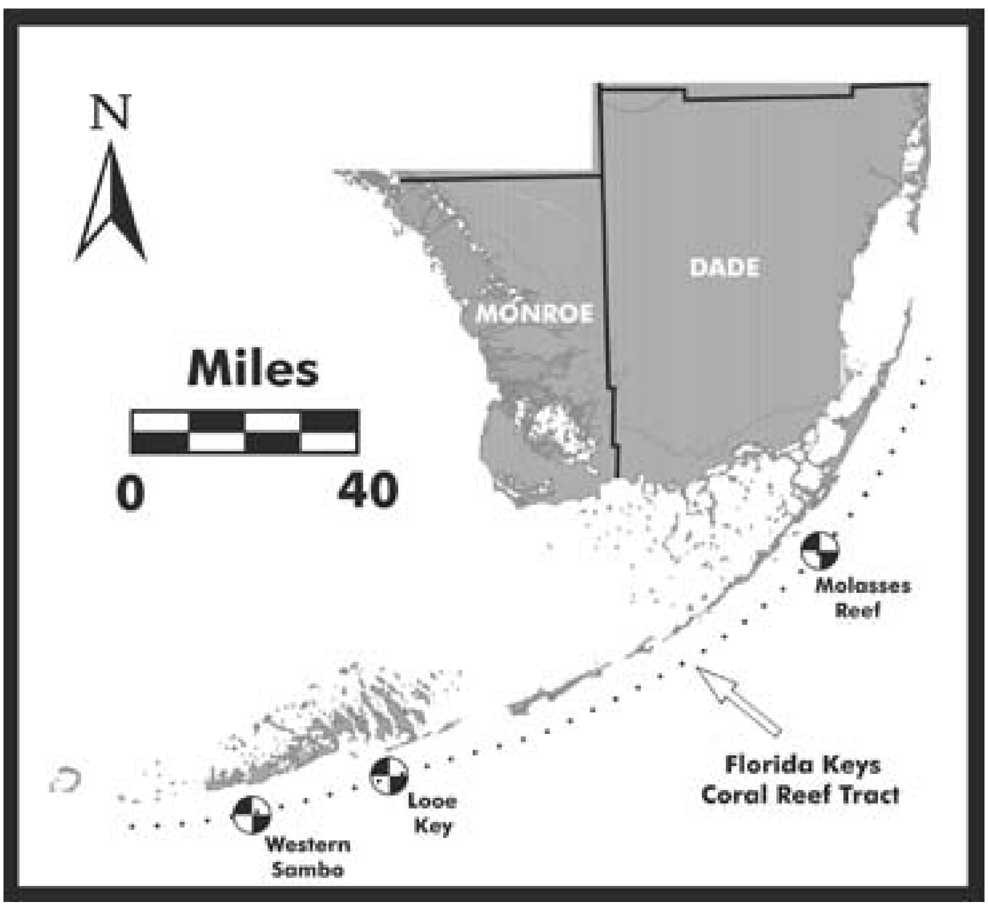

Figure 1. Base map showing location of Western Sambo Reef, Looe Key Reef, and Molasses Reef. The modern coral reef tract (represented by the dotted line) is located several miles offshore and is composed of numerous patch reefs, many of which exhibit spur and groove morphology.

Spur and Groove Morphology

The term "spur and groove" was first used by Shinn (1963) in reference to coral reef morphology identified at various patch reefs along the Florida Keys Coral Reef Tract (Figure 1). Previously, this reefal structure was referred to as the buttress zone at a reef in the Pacific Ocean (Odum and Odum, 1955). In describing spur and groove morphology, Shinn (1963) stated:

> The "spur and groove" system is a geomorphic feature that is present on the seaward side of most reefs ... Externally, spurs are coralline fingers as high as 30 feet that are separated by grooves ... On Florida reefs, the spurs vary in width from