Bubbles of surprise

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Oil and gas seeps are widespread at the continental margins and have the potential to provide a huge natural gas resource. On the sea floor seeps leave characteristic geomorphic 'signatures' such as pockmarks, piping and rills, while on land they create brine pools and mud volcanoes. Carbonate bodies in various shapes and settings are also an important signature. Seep features are common in the sedimentary record. Many features usually interpreted as paleokarst would be better interpreted as paleoseeps. Often, seeps associated with human activities seem to initiate submarine landslides. The origin and behaviour of seeps is readily explained by the burial of organic matter in sediment during the global Flood, the diagenesis of these sediments, and the changes in global climate during and after the Ice Age.

It seems a general feature of human thinking—science being the epitome—that neatly elaborated schemes and theories gradually become like icons. Getting rid of one feels like giving up a limb or an eye, no matter how high the pile of counter-arguments grows. For example, the discovery of hydrothermal vents in the 1970s offered a clear proof of significant dynamic connections between the lithosphere, hydrosphere and biosphere. Yet these extremely interesting geomorphic features were somewhat kept in the collective memory as highly peculiar and playing a lesser role in the global geosystem. It was only when the vent chemosynthetic ecosystems were discovered that the importance of hydrothermal vents was globally acknowledged.

Similarly, when offshore and coastal oil and gas seeps were discovered in hydrocarbon provinces, they were again reduced to local oddities. The use of remotely operated submersibles in the 1980s and 1990s enlarged the area of known seep sites far beyond the hydrocarbon provinces. It was found that they encompassed practically the whole of the continental margins where they constitute a general feature of the geohydrologic system (Figure 1). Seeps are also present on the continents and in some cases submarine seeps are hydrologically connected to the terrestrial groundwater systems. Seep output includes natural gas, carbon dioxide, nitrogen, hydrogen sulfide, other gases and oil. Many seeps support chemosynthetic biological communities (Figure 2).

One extremely spectacular source of seeps is methane hydrate—a crystalline combination of natural gas and water which looks remarkably like ice but burns if it meets an open flame. Chemists discovered methane hydrates in the 19th century but it was not until the end of the 20th century that geoscientists discovered them in marine sediments. Oceanographers first drilled through methane hydrate

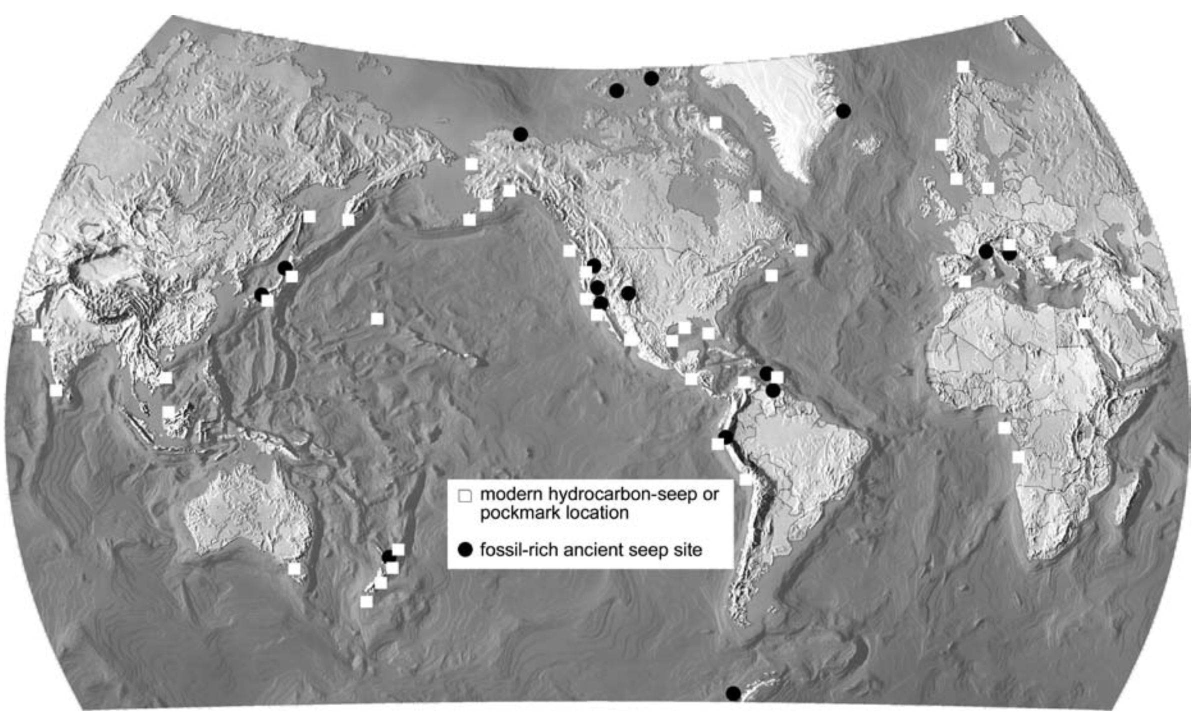

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Figure 1. Global distribution of modern and ancient fluid seeps. Modern seep and pockmark distributions are from Hovland and Judd,[12] with additions from Moore.[3]

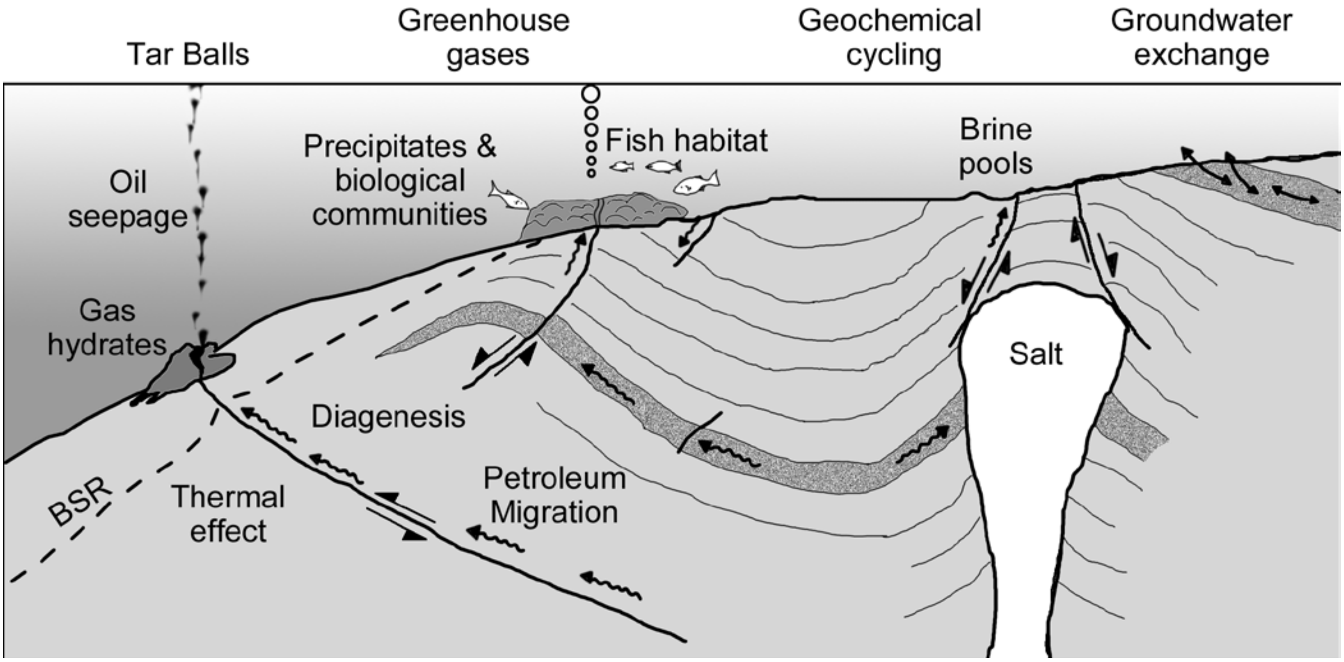

Figure 2. *Schematic cross section of seepage system showing the role of faults, stratigraphy and salt in focusing fluid flow (BSR = boundary of saltwater regime). Seafloor manifestations of seepage include direct expulsions of oil and gas, gas hydrates, biological communities and precipitates of various types (from Moore, used with permission).*[3]

deposits unintentionally in 1970[1] and for the following 20 years they avoided them for fear of encountering overpressurised gas pockets. Their cores never yielded this elusive substance because it melted on its way up to the ship. Only after the discovery of pockmarks, or ocean bottom pits, were suspicions directed towards methane hydrates as the possible cause. Only then were unusual precautions taken when recovering cores, and samples of methane hydrate obtained.

The gas yield of these cores was staggering: 10–30 litres of gas per litre of sediment![1] No wonder this discovery stirred up heated discussions about the potential resources of natural gas in this unexpected geological setting. Estimates run from ecstatic through optimistic to moderate. One thing seems clear, there are unexpected resources down there, which may give mankind some relief in the crazy race for fossil fuels.

It has been found that seeps have lower temperatures and lower flow rates than hydrothermal vents. They are associated with consolidating sedimentary basins, in most cases at continental margins, whereas vents lie on young oceanic crust and are driven by temperature contrasts between magma and seawater.

Quite predictably, petroleum geologists were the first to realise the importance of these geomorphic features and they dedicated a symposium to this topic at a Meeting of the American Association of Petroleum Geologists in Monterey, California, in 1999.[2] Some of the conclusions of this symposium—compiled by Moore[3]—are extremely interesting and have triggered this paper. These conclusions seriously impact our understanding of how marine sediments actually form because their depositional dynamic is very different from standard sedimentological thinking. Yet, till enough data accumulates, sedimentology continues to follow its standard, uniformitarian path.

Seep products

Once direct investigation of seep sites was possible and later, as new, more accurate remote sensing methods became available, it was discovered that submarine seeps left, and continue to leave, a geomorphic signature that is quite similar to continental seeps. Fluid-induced sea bottom geomorphic features include seep precipitates (carbonates and hydrates), pockmarks, piping and rills. On the continents seeps create brine pools, mud volcanoes and other local features. As for their scale, seeps may range in size from metres to kilometres. Some of the most sedimentary-significant seep signatures are the carbonate bodies (irregular mounds, dykes, flat hardground-type surfaces), many aligned along fault lines. In some cases, inside these carbonate bodies small-scale parallel, ring and columnar structures are present, very much resembling speleothems.[3] Cylindrical to conical structures have been recently identified at some locations on the ocean bottom (Figure 3a, b). Many paleoseep carbonate bodies have already been revealed which are practically identical in structure with modern ones; they are said to offer great hopes for paleoclimate, hydrological, chemical and biological reconstructions.

Figure 3. *Sketch of seep structure from Smooth Ridge in Monterey Bay (based on Moore).[3] Diameter of sample is about 30 cm. These features probably form in the shallow subsurface and are exhumed by submarine erosion. Once buried in deeper sediment and subjected to recrystallisation, they could easily look like stalagmites and stalactites (especially when the central canal is preserved).*

Paleoseeps seem to have a given lifetime, being buried by newer sediments after 'death'. So far, about 17 macrofossil-rich hydrocarbon seep systems have been recognised in the Phanerozoic strata of Jurassic to Pliocene age. There seems to be a gap in hydrothermal vent and cold seep deposits for the Permo-Triassic. This, I believe, may be due to the merging of all landmasses into the supercontinent Pangea and the consequent modification of ocean bottom magmatism, continental margin geometry and also of the pattern of ocean water circulation. Cold, fossil seep deposits appear to be concentrated in the Lower Cretaceous and Upper Eocene to Miocene, for reasons that remain unclear. I suspect there could be a connection between the Alpine-Carpathian-Himalayan multiphase orogeny (which covers this period) and the seep deposit concentration.

Terrestrial seeps have generated important local features like the famous tar pool at Rancho La Brea with its unique collection of fossils and the cave, Movile, in Romania. Here 32 new species and 2 genera of invertebrates were discovered thriving on sulfur-rich seeps inside the cave[4,5] in what appears to be the most easily accessible chemoautotrophic ecosystem known so far. There are also scores of travertine deposits around the world, especially on carbonate platforms.

Given all the above, it is obvious that one may hardly claim that, whatever the overall flux of seeps is today, we should expect similar fluxes in the geological past. Seeps do not seem to have heard of the uniformitarian principle yet.

Seep hazards

Fluid seepage has been found to associate with many types of geologic hazards. There is a link between fluid expulsion and slope failure (seepage-induced spring sapping) and models have demonstrated this link in a number of settings.

As hydrates accumulate on the seafloor and in the shallow subsurface, human activities at those localities (such as drilling, laying of undersea cables etc.) could de-stabilise the accumulations. Circumstantial evidence connects such activities to development of the basal shear plane of submarine landslides near the base of gas-hydrate stability zones.[2,3]

A more subtle kind of hazard is for … sedimentology! Fluids inside sediments are known to be mobile. We need to identify their migration pathways through the dewatering, compacting and deforming sediments to better understand the hydrogeologic and sedimentary processes in sedimentary basins and continental margins. Stratigraphy, structure and diagenetic features—including gas hydrates—are essential controlling agencies of these pathways. But fluid circulation is not always smooth, as it turns out. Consequently, one may assume that seeps also play an important role in the reshaping and disturbance of initial sedimentation patterns. As karst formation and karst evolution show, circulating fluids inside diagenised rocks sometimes affect stratigraphic features. Therefore one may reasonably assume that fluid circulation inside unconsolidated sediments must play an active role in settling sedimentary structures.

The sedimentological hazard also associates with ecosystem hazards. Massive seeps would almost certainly cause large numbers of benthic creatures to perish in a violent manner and sure enough, mass extinctions of such creatures in the fossil record are dramatic depictions of violent death. Even neritic and planktonic extinctions are expected to occur when important volumes of gaseous seeps bubble to the ocean surface. Thus one may conclude that mass extinction horizons inside the geological record would at least sometimes indicate massive episodes of seeps.

Finally, one very important hazard (but also a global modelling agency) induced by gas seeps is methane input into the atmosphere. Methane is 10 times more powerful as a greenhouse gas than carbon dioxide. Consequently massive melting of hydrates and the ensuing release of methane gas could raise global temperatures. There are evidences that carbon isotopic ratios in the ocean off the coast of California had significantly shifted during the Late Quaternary.[1] Some assume that a slight warming of ocean waters triggered a massive melt of methane hydrates which escaped to the atmosphere and induced a strong greenhouse effect.[1] According to others, the release of methane was due to the 90 metre swelling of sea levels (due to the melting of the ice caps) that led to the covering by relatively warm waters of continental gas hydrate deposits.[1]

Whatever the release mechanisms, it is now more or less agreed that methane hydrate deposits are a strong climate controlling element and there is no secret that if today's global warming is real, then methane input into the atmosphere will increase and consequently the warming will be even stronger.

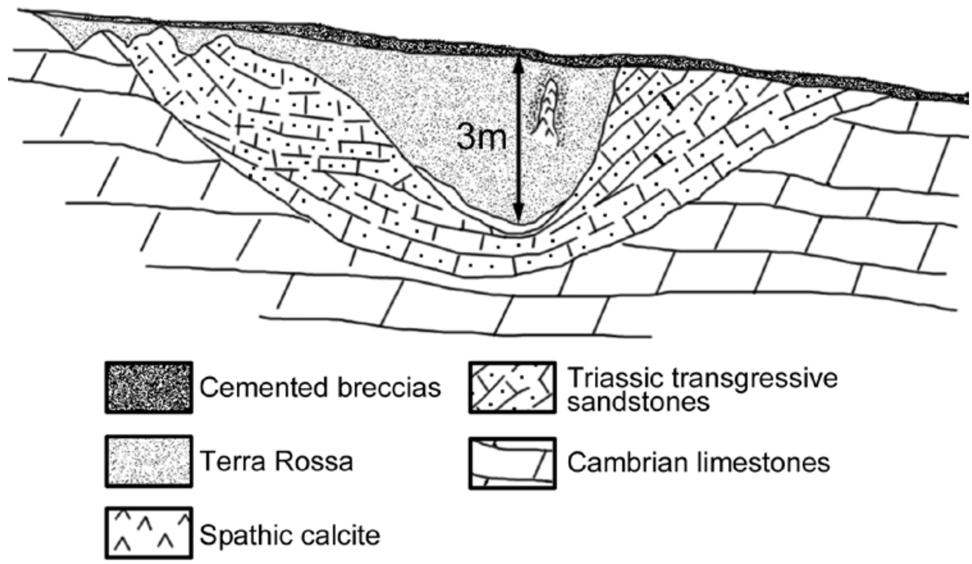

Figure 4. *Schematic section of a doline on Mount Saint Giovanni, Sardinia (from Bini* et al.[8]*).*

A creationist interpretation

To my knowledge, Michael Oard was the first scientist to approach fluid seeps—one of their geomorphic signatures, pockmarks, in fact—from a creationist point of view.[6] Oard emphasised the fact that pockmarks are not found in pre-Pleistocene marine sedimentary rocks, which must therefore have been rapidly deposited during the Flood.

I believe that pockmarks actually exist in the geologic record and may be associated with most of the features that uniformitarian geology describes as paleokarst (pockmarks are known to be present in carbonate muds). As I have shown in a previous paper,[7] these paleokarst features never display evidence for the existence of proper karst geosystems. Morphologically they are all surficial features rarely exceeding several metres in depth and are filled with newer sediments. One good example is provided by 'dolines' exposed in the Santa Barbara Mine in Sardinia (Figure 4).[8] The funnel-shaped alleged 'paleokarst' features are sculptured in Cambrian limestones and are filled by transgressive Triassic sandstones. The Triassic sandstones are in turn carved out by another 'doline' perfectly superimposed on the one in the Cambrian limestones. The secondary doline is filled by Terra Rossa. This remarkable setting is said to be the rule in this area. The way the section in the mine is presented by the authors reveals an unusual sedimentological feature. The bedding planes of the transgressive sandstones are not horizontal (as expected and as exists in the underlying Cambrian limestones), but the bedding follows the geometry of the 'doline' walls, which is curved. Such an unusual setting is difficult to explain and if recurrent (as the authors claim) becomes an enigma. If, instead of a karstification processes, we interpret the features as pockmarks (and consequently seeps), there are virtually no questions remaining.

The majority of known paleokarst features are pit-shaped. Some resemble piping and rills. Lithologically, the most frequent feature is a breccia-type formation. Carbonate sequences resembling hardgrounds are also present and so are rare speleothems. All of these are highly compatible with paleoseep signatures as presented above. If this is true, then the alleged paleokarsts may have nothing to do with subaerial conditions. They may all have formed on the sea bottom on unconsolidated sediments. Consequently, a more appropriate term for them should be 'pseudokarst'.[9]

It is conceivable that pre-Flood seeps were present and if so, the most ancient alleged paleokarst features may well, as I suspect, not be karst at all.[7] As the great majority of signature-relevant seeps are hydrocarbon generated, one may assume that seeps could only have occurred after the accumulation of 'Biotic' rocks (if such ever existed) as described in Walker's Biblical geologic model.[10] There is one interesting question to be raised at this point: since fluid seeps appear to be a characteristic of continental margins solely, where were continental margins before the Flood? Could we associate pre-Flood seep signatures (if they still exist and can be identified) with continental margins? If we manage to develop a reliable method of identifying paleoseep signatures, we may add one more marker for continental margin identification and thus eliminate some of the inherent uncertainties of sedimentology and petrography.

In the same line of reasoning, one may presume that during the Genesis Flood any pre-Flood seep signatures that may have been present would have been overwhelmed by the intense processes associated with the cataclysm. The mechanical and thermo-chemical changes inside sediments during the Flood most probably intensified seepage but the geomorphic signatures must have been incorporated in regional stress and strain induced structures. When present in carbonate formations, they may reasonably be associated with intrastratal karst.[7]

After the Flood, until ocean temperatures dropped significantly, gas hydrate formation would have been practically impossible. However, decomposition of the immense mass of dead plants and animals buried in the Flood sediments would have generated a huge volume of gas. Consequently, we should expect the paroxysmal seepage of methane and other decomposition gas within years of the end of the Flood. This would have disturbed the initial sedimentary structures, making the work of geologists today pretty much guesswork. Once ocean temperatures dropped (possibly 500 years after the Flood, at the glacial maximum, as Oard suggested[11]) methane hydrates could have formed. Thus, once a part of the seeping methane could be stored seep intensity would diminish.

Post-Flood accumulation of organic matter in sediments was, and is, much lower than previously occurring during the mass burial of the biosphere during the Flood. Therefore, it is to be assumed that after a maximum seepage rate sometime after the Flood, a steady decrease in seep activity should be expected. It may well be that the activity we see today is just a fraction of the intense seepage occurring during the Ice Age. The huge volume of methane released into the atmosphere at that time may have triggered a global warming and consequently led to the deglaciation.

Seep possibilities

Seeps, those surprising, little-understood geologic features provide an abundance of material for exciting hypotheses leading to improved geologic understanding. Far from being established scientific knowledge, the issues presented here are still speculative and no doubt many useful possibilities and scenarios have escaped my scrutiny. Seeps are one area where creation scientists can lead in science because the evolutionist scientific establishment seems reluctant to fully embrace the implications of seeps for the geosciences. I therefore invite fellow creation scientists and everybody interested in this topic to embark on a potentially great adventure, which, with appropriate support, may well include research programs of field and laboratory investigations.

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