Some of the arguments used in this report have logical weaknesses. They claim that something is missing: charcoal mixed into sand, soil layers, deep erosion cuts, meteorites, unbroken plant fossils. The search obviously did not examine every possible location because that would require dismantling the entire ridge boulder by boulder. Only readily available exposures were examined in a non-destructive way, and even then the search was not comprehensive.

These observations at and near Dinosaur Ridge challenge the evolutionary and uniformitarian scenarios for the geologic history of the Morrison and Dakota Formations at this hogback. Though the champions for those scenarios raise their objections when we meet at Stop 7, the general public tends to be sympathetic to the catastrophic scenarios. They can see the pollen samples with their own eyes and notice that the fossil pollen from the Hakatai shale looks similar to the modern pollen under the microscope. They can relate an average sedimentation rate over millions of years to the size of the pollen they are examining. They can see the mixture of plant matter and sand in the rocks and can relate to the density differences between plant matter, water, and sand. There is no problem envisioning the plant matter floating away under uniformitarian conditions. They can relate to the rapid decay and scavenging of dead animals along highways and to the obliteration of footprints at seashores, playgrounds and feedlots, necessitating rapid burial if preservation is to occur.

Dinosaur Ridge is considered by some as a monument promoting the evolutionary scenario and the passage of millions of years. The physical evidence, however, speaks more loudly in favor of catastrophic processes. The contrast between the scenarios can give rise to sharper reasoning skills as one considers the evidence supporting each side.

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HYDROTHERMAL VENTS AT DEEP SEA SPREADING RIDGES: MODERN-DAY FOUNTAINS OF THE DEEP?

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Abstract

Deep sea hydrothermal vents associated with mid-ocean spreading ridges have implications for both creationists and evolutionists with regard to origins of terrestrial massive sulfides, geochemical flux into ocean waters, heat flow, and dating of mid-ocean rifting events.

Description

Spreading ridge hydrothermal vent systems are areas of emission of heated waters on the spreading ridges of the ocean floors. An explosion of research in recent years, using submersibles and sophisticated recording and collection equipment, has produced a huge amount of data, much of which is of interest to creationists.

Spreading ridge hydrothermal vent systems have been found in the Dead Sea, on slow spreading ridges, in back arc basins, and on fast-to-medium-spreading ridges (Rona, 1983). The term "fast" or "slow" spreading ridge does not refer to measured observations, but rather to assumptions of seafloor ages based on magnetic patterns on the sea floor in relation to radiometrically determined rock ages. The mid-Atlantic ridge is considered to be a slow spreading ridge and the Eastern Pacific ridge to be intermediate to fast.

This paper will concentrate on data gathered from hydrothermal systems located on the Eastern Pacific Ridge (EPR) because these have been the most extensively studied thus far. These vent systems are characterized by massive sulfide deposits (mostly Cu, Pb, and Zn), by high temperature water emissions, often accompanied by particulate (vents may be called "black smokers" or "white smokers"), and by an unusual biota, including sulfur-oxidizing bacteria and odd-looking tube worms.

Although chance played a large part in the discovery of the first hydrothermal vents, the development of more sophisticated models of hydrothermal distribution now predict that hydrothermal activity should be found on topographic highs along the ridge crest (Francheteau and Ballard, 1983). Estimation of the distribution of hydrothermal mineral deposits or high intensity hydrothermal systems capable of producing such deposits range from one such occurrence every 15-100 km along slow spreading centers to every 1-100 km along intermediate-to-fast-spreading centers (Rona, 1983).

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Implications for Terrestrial Deposits

Modern hydrothermal vent systems should be taken into account in Nutting's model of evaporite formation, (Williams, 1989), which posits a hydrothermal vent origin for bedded salt deposits, but lacks observational support. In actuality, modern sea floor hydrothermal vents are found to produce massive sulfides, not bedded salt deposits, from interaction of seawater with basalt.

More and more, continental massive sulfide deposits are being reinterpreted in the light of hydrothermal origins. For example. Holmen and Delaney (1985) explained the differences in geochemistry between a quartz-sulfide vein and wall rock in the Bay of Islands ophiolite as reflecting alteration of wall rock gabbro by a hydrothermal fluid moving through the system. Robertson and Boyle (1983) have interpreted the huge region of metalliferous sediments around the Mediterranean and Persian Gulf in terms of deposition from hydrothermal processes, using comparisons with data from the EPR at 21°N, the Galapagos, the hydrothermal sites on the Juan de Fuca ridge in the Pacific, and from the Trans-Atlantic Geotraverse (TAG) hydrothermal field on the Mid-Atlantic Ridge.

The deposits most intensely studied have been the Troodos massif and associated sulfides in Cyprus. Oudin and Constantinou (1984) claimed to have identified black smoker chimney fragments and fossilized worm tubes in Cyprus sulfides. Fossil worm tubes have also been reported from the Semail ophiolite in Oman (Haymon et al., 1984).

Oudin et al. (1981) inferred similarity of origin between the EPR at 21°N and Cyprus sulfides because of: 1) similarity in petrologic texture and facies, and 2) paragenetic similarities, essentially the presence or absence of trace minerals. For example, jordanite, a rare Pb-As sulfide, is found in both 21°N and Cyprus samples, while tellurides and cassiterites, which are common and characteristic of major volcanogenic deposits, are unknown at the two sites. Moores and Varga (1985) examined three structural basins in the Troodos ophiolite and suggested that the normal faults defining the grabens once served as channels for the hydrothermal fluids that produced the massive sulfides. Schiffman et al. (1985) used the O-isotope composition of metamorphosed sheeted dikes of one of the grabens to correlate different grades of metamorphism with hydrothermal alteration. They found rocks with low $\delta^{18}O$ compositions and calculated that they were altered by fluids hotter than 350°C. The amount of oxygen isotope found in the rock can be correlated to temperature of the water at the time of rock alteration, with $\delta^{18}O$ decreasing with increasing temperature in natural waters.

Rates of Formation of Deposits

Measurements of heat flux from black smoker chimneys at 21°N show so great a rate of heat loss that it is unlikely that the vents are a steady state phenomena, and lifetimes of about 10 years are estimated for individual vents, in keeping with the time estimated for sulfide mounds to form by precipitation, and the age distribution of clams near the vents (Macdonald et al., 1980).

Converse et al. (1984) measured a precipitation rate of .45 grams FeS per second for a sulfide mound 15 meters (m) in diameter and 1.3 m in height. From this, they estimated that the sulfide mounds can form in 70-85 years from settling of sulfide particles alone. They noted, however, that the process of forming sulfide chimneys, as opposed to mounds of massive sulfide, is more efficient in extracting sulfides. Hekinian et al. (1983) actually witnessed a sulfide chimney being formed and measured a growth rate of 5-10 cm in length per day. They came to the startling conclusion that all the sulfides seen in the central graben of the study area (EPR near 12° 50'N) were formed within a time span as short as a few years. This was corroborated by Thorium dating of one dive sample, which gave 20 to 60 years as the sample's age. They extrapolated the measured rate of growth of the observed chimney and calculated that a cylindrical shaped chimney with an internal and external diameter of 3 cm and 10 cm respectively, with density of 2.9 gram/cm^3 would increase its mass at about 1.6 kg/day, and an average sized conical shaped sulfide edifice (6 m in height and 3 m in base diameter), weighing about 41 tons, would be built in about 70 years. However, Converse et al. (1984) calculated that, at a 100% phyrrhotite removal rate, a single sulfide mound, if formed solely of broken fragments of sulfide chimneys could form in a minimum of 2-3 years.

Converse et al. (1984) estimated that hot springs are active for a maximum of 5000-40,000 years. What they were actually saying, however, is that, based on heat flow considerations, the maximum lifetime of a hot spring is 1/8 to 1/9 of the time required for the oceanic crust to move away from the ridge crest to the full length of hydrothermal convection cells in the ocean crust, which they assumed to be 7.5-10 km perpendicular to the ridge crest. The 5000-40,000 year lifetime figure came from assuming a steady state ridge-spreading rate of 3 cm/yr, so that, for example, crust which is 540 km from the ridge crest would be 18 million years old. The question of the actual age of the ocean crust is discussed in the last section of this article.

Implications for Geochemical Composition of Oceans

Understanding the chemical influx from hydrothermal vents into the ocean could lead to an understanding of the global geochemical mass balance and budget of the ocean.

The geochemical flux of hydrothermal waters at mid-ocean ridges has been used to explain the differences between the input of rivers into the ocean and the geochemical composition of the ocean. Specifically, if there were no buffering action, a continual flow of river water would turn the ocean into an alkaline, bicarbonate lake (Thompson, 1983). It has been shown that the overwhelming proportion of the mass flux of hydrothermal fluid is lost to the water column at mid-ocean ridges, with only a small percentage localized in vent precipitates, although ore retention is much more efficient in sediment-covered spreading centers such as the Red Sea and Guaymas Basin of the Gulf of California (Edmond, 1984).

Calculations utilizing data from the EPR at 21°N and the Galapagos Rift (Corliss et al., 1979; Edmond et al., 1979; Von Damm, 1983) indicate that high temperature reaction sites in hydrothermal systems (at least 350°C) act as sinks of Mg and SO_4 and as sources of Si, Ca, K, Rb, and Li (Edmond et al., 1979; Thompson, 1983).

The calculations are especially successful in showing that the hydrothermal sites, acting as a sink for Mg, serve to balance the excess Mg supplied by continental inflow as compared to the composition of normal seawater (Thompson, 1983; Edmond et al., 1979; Edmond, 1982).

Similarly, the supply of Ca from hydrothermal sites could account for the apparent "excess" amount of calcium carbonate in the geologic column compared to that expected solely from the weathering of primary igneous rock (Edmond, 1982). For a vent field on the Galapagos spreading ridge, Edmond et al. (1979) calculated fluxes of between 4.3 and 2.1 x 10^{12} moles/year, compared to a river value of 12 x 10^{12} moles/year. Since approximately 75% of the latter is due to the weathering of carbonate rocks, they concluded that the ridge input doubled the flux of primary, igneous derived Ca to the oceans, sufficient to account for the anomalous abundance of carbonate rocks in the geologic record as deduced from a purely continental balance. From a creationist viewpoint, it could be that massive hydrothermal vent activity (reactions of seawater with hot, fractured basalt) during the Flood did indeed act as a source of Ca for the formation of the present-day terrestrial carbonate rocks.

The EPR and Galapagos data also indicate that hydrothermal ridge processes could supply the flux of non-radiogenic Sr necessary to maintain the observed $^{87}Sr/^{86}Sr$ ratio observed in seawater (Von Damm et al., 1983). In addition, variations in $^{87}Sr/^{86}Sr$ ratios over time observed in marine carbonates may be explained by variations in the relative importance of Sr supply from mid-ocean ridges and continents (Edmond, 1982; Turekian, 1983).

An important implication for creationist theories would be the contribution of any deep sea hydrothermal vents toward the heterogeneousness of ocean waters. Particularly for a Flood model, the contribution of vent waters to the heterogeneousness of ocean water could be important to the survival of freshwater and saltwater organisms (Smith and Hagberg, 1984). If the vents are the result of deep circulation of sea water in fractured crust, superheating of the water, and subsequent exiting, then it follows that increased volcanic activity and fracturing of ocean crust during the Flood could have increased the magnitude of vent activity and thus the influx of vent waters into the ocean.

Problems in calculating the geochemical fluxes of hydrothermal sites include: uncertainty of estimates of rock/water ratios and total amount of ocean crust affected by hydrothermal activity (Honnorez, 1983; Thompson, 1983), contamination and dilution of water samples (Von Damm et al., 1983), and lack of convincingly representative and complementary samples of both altered solutions and altered solids from a single system (Mottl, 1983). In addition, all experiments have been done with the assumptions that no significant recirculation occurs between the time of seawater entering permeable crust and exiting at hydrothermal vent sites, and that the basalt that forms the ocean crust is of relatively uniform composition (Edmond, 1984). While the assumptions are not unreasonable, variations in these conditions at the limited number of sites sampled coupled with the geographic closeness of the sites requires that the estimates of geochemical fluxes at hydrothermal vents be regarded strictly as preliminary. In addition, the discovery of four seafloor vents on the Mid-Atlantic Ridge (Rona et al., 1984) indicates that the contribution of slow-spreading ridges must also be considered when calculating total geochemical flux into the ocean (Mottl, 1983).

Biological Aspects of Hydrothermal Vents

Tube worms (phylum Pogonophora) and clams make up 90% of animal biomass at hydrothermal vent communities (Jannasch, 1983). Primary production of organic carbon by chemosynthetic sulfur-oxidizing bacteria has been proposed to provide the base of the food chain for the animal populations (Jannasch, 1983) and has been supported by radioisotope studies (Grassle, 1983). This is a unique trophic situation because, while terrestrial chemosynthetic bacteria are well known, the vent animals are the only ones known to thrive on chemosynthetic products derived from volcanic energy (Grassle, 1982). Analysis of fluids, direct observation, and analysis of animal specimens indicates three locations of chemosynthetic production: 1) within subsurface vent systems at elevated temperatures, 2) in microbial mats immediately surrounding the vents, and 3) in various symbiotic associations with invertebrates (Jannasch, 1983). The discovery of symbiotic bacteria/tubeworm associations at hydrothermal vents has led to the detection of similar relationships in pogonophorans in marine fjords, and may apply to other organisms as well (Desbruyeres and Laubier, 1983).

Another source proposed for the base of the food chain is particulate organic matter advected from the photic zone by bottom currents produced by rising hot water from vents (Jannasch, 1983). Strong evidence against this hypothesis, however, includes the dense distribution of well-separated populations around small vents (Desbruyeres and Laubier, 1983), calculations of the amount of matter necessary to support the community, and evidence that hot water does not rise above the bottom 10% of the water column (Jannasch, 1983; Desbruyeres and Laubier, 1983). At Axial Seamount on the Juan de Fuca Ridge, however, the biologic "halo" around the vents extends for hundreds of meters (Arquit et al., 1984). One possible explanation for this area is that the vent site is very shallow, about 1500-1600 m.

Species unique to the vent systems include a dozen new families or subfamilies and many more new genera (Grassle, 1983). Thirty-five new species have been collected from Explorer Ridge, Juan de Fuca Ridge, and the Oregon coast alone. Although the quantity of biomass is very high at vent sites, diversity of species is low compared with deep-sea environments elsewhere (Grassle, 1982). Four major species dominate the vents at 13°N, 21°N, and the Galapagos Rift: giant tube worms *(Riftia pachyptila)*, large white clams *(Calyptogena magnifica)*, an undescribed mytellid mussel, and the Pompeii worm *(Alvinella pompejana)* (Desbruyeres and Laubier, 1983).

Metabolic rates and growth supply of mussels at hydrothermal vents are food-supply dependent. Growth rates are highest close to the vents, the presumed source of molecular and bacterial energy. Rates may also change in response to rapid changes in temperature of food supply due to fluctuations or cessation of hydrothermal activity (Grassle, 1982). Direct growth measurements and natural radionuclide shell contents of bivalves show very high growth rates, a 1-4 cm / yr average (Desbruyeres and Laubier, 1983). Because life spans of individual vents are short, less than 100 years, primary consumers must 1) be able to settle quickly, 2) grow fast and reproduce early, and 3) disperse easily when conditions deteriorate, by means of larvae or juveniles (Grassle and Grassle, 1974). Although conditions typify an ecologic strategy normally associated with small organisms, the vent site organisms are unusually large (Desbruyeres and Laubier, 1983). One exception is the southern Juan de Fuca ridge, whose vent organisms seem to be less robust than those found on the EPR and Galapagos (Koski et al., 1982).

The biology of dispersal states of vent organisms is an unsolved problem. Suggested means for dispersal include long pelagic life for larvae passively carried by along-strike currents, deduced for Galapagos mussels from morphology of larval shells; and actively swimming adults drifting along rift currents (Desbruyeres and Laubier, 1983).

The possibility that organic compounds may have formed abiologically in deep sea hot vents suggests to evolutionists that the vents may have been places where life originated (Jannasch, 1983; Corliss et al., 1981). The problem remains, however, of differentiating abiologically produced organic compounds from those produced by chemosynthetic bacteria within the vent system (Jannasch, 1983), although technology has improved to the point where scientists can collect samples of uncontaminated vent fluid in order to isolate the compounds.

Another puzzle for evolutionists is that two species have been found at hydrothermal vents that had previously been assumed to have become extinct in the Late Cretaceous: the limpet *Neomphalus fretterae* and the stalked barnacle *Neolepas zevinae* (Jones, 1984). It has been postulated that these two species took refuge at relatively shallow hydrothermal communities near continents or around islands, and migrated to other spreading centers to escape predation pressure (Jones, 1984). In addition, the resemblance of modern organisms to fossilized worm tubes in the late Cretaceous Semail ophiolite of Oman (Haymon, et al., 1984) presents evolutionists with the problem of whether the Cretaceous worms were the ancestors of the present-day worms, or whether there was parallel evolution. Both the "survival" of supposedly extinct species and the resemblance of "ancient" fossilized worms to modern worms support the creation model better than the evolutionary model.

Implications for Measured Heat Flow in Oceans

Hydrothermal circulation at mid-ocean ridges appears to explain the discrepancy between measured heat flow through sea floor, and values predicted for conduction through a convecting lithosphere (Macdonald, 1982a; 1982b; 1983). The basic model for hydrothermal circulation in the ocean crust was first formulated by Elder (1965): seawater in permeable ocean crust is heated above subaxial magma chambers and driven upward, dissolving metals from the rocks it passes through and re-precipitating them on the ocean floor as massive sulfides (Rona, 1982). See Figure 1.

Thermal models for spreading ridges differ in predicting steady state versus transient magma chambers. Factors that must be considered include the rate at which cracks propagate downward in the axial zone versus the rate of clogging of the cracks and hydrothermal precipitation (Macdonald, 1983). While some models postulate that no magma chamber at any spreading rate can remain in a steady state because of freezing of the magma (Lister, 1983), seismic and petrologic data indicate steady state magma chambers at faster spreading rates. Most petrologic studies indicate small steady state magma chambers even at slow spreading rates (Macdonald, 1982a; 1983; van Andel, 1983). Problems with models of hydrothermal heat flow include poorly constrained estimates for both the magnitude and areal distribution of hydrothermal heat loss at spreading centers, and also for the depth and rate of crustal fissuring. There are also assumptions of two-dimensionality (Macdonald, 1983).

Mid-Ocean Rifts, Hydrothermal Activity, and Continental Drift

Genesis 7:11 says ". . . on that very day, the springs of the great deep broke through" (New Jerusalem Bible, also translated as "fountains of the great deep" in the New American Standard). The deep sea hydrothermal vents are probably not the springs or fountains mentioned in Genesis 7:11, since they seem to be a side effect of seawater flowing through heated, fractured ocean crust, and not exit sites for an underground source of water. They are associated with mid-ocean spreading ridges, however, and the question remains of whether the mid-ocean rifts are relicts of volcanic activity during the Flood or afterward.

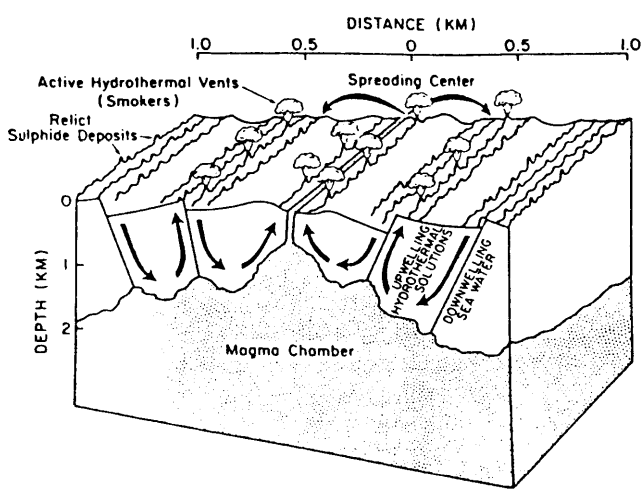

Figure 1. Schematic block diagram illustrating hypothetical hydrothermal ore-forming system at a seafloor spreading center like the East Pacific Rise. (from Rona, 1982)

Genesis 10:25 says "To Eber were born two sons: the first was called Peleg, because it was in his time that the earth was divided . . ." (New Jerusalem Bible). Could this be a reference to a post-Flood continental rifting event (Peterson, 1986)? There is a large body of geologic and geophysical evidence supporting the concept of continental drift, including symmetrical magnetic lineations on either side of mid-ocean ridges, similar fossils and geologic strata on continents now separated by ocean, and geophysical records of subducted oceanic plates beneath continental edges. The question remains of how much of the present-day ocean's crust existed before the Flood, how much was produced during the Flood, and how much may have been produced during a post-Flood, Pelegian rifting event.

Deep fracturing of basaltic crust and circulation of ocean waters during the Flood, whether or not associated with continental drift, may have led to massive deposition of sulfide particulate and formation of sulfide chimneys on the ocean floor. If the present-day terrestrial massive sulfide deposits were all formed in the Flood, it seems unlikely that there would have been sufficient time or suitable conditions for establishment of vent communities of clams, tube worms, and mussels. However, if hydrothermal activity continued on a lesser scale after the Flood subsided, but before rifting was completed, this may have allowed the establishment of biological communities whose fossils have been found in the Troodos sphiolite (Oudin and Constantinou, 1984) and in the Semail ophiolite in Oman (Haymon et al., 1984). Uplift during the time of Peleg would then have brought the ophiolites and sulfide deposits above the ocean. In this sense, the massive sulfides produced by hydrothermal vents may act as a sort of time clock, in that the presence of fossils of vent communities in massive sulfides may indicate an area where uplift occurred after the Flood.

The possibility also exists that the biologic fragments found in terrestrial sulfides are relicts of pre-Flood vent communities, which were uplifted during the Flood. In this case, the terrestrial sulfides may mark an area where the pre-Flood ocean crust was close to a source of volcanic energy, an area of weakness along which later rifting occurred.

A question that does not appear to have been asked by researchers working on the vents is, if the ocean crust were formed by conveyor-belt type spreading away from the ridge crest, why is not the ocean floor as enriched in sulfides as the ridge crests? If sea floor spreading really has been occurring at a slow rate of cm / yr over millions of years, the surface of the ocean crust should be dotted with sulfide chimneys, sulfide mounds, and fossil vent communities, under a blanket of sediment of course. However, if spreading occurred very quickly, on a time scale of months or years instead of millions of years, there might not have been enough time for hydrothermal alteration and sulfide deposition, and the crust would retain a basaltic composition. This might be a fruitful field of investigation for creationists working on the Flood model.

Conclusion

The uniformitarian assumptions of most researchers on hydrothermal vents present them with many questions, including the origin of the strange life forms around the hydrothermal vents and the problems of size differences between present seafloor hydrothermal sulfide deposits when compared to terrestrial massive sulfides. For creationists, however, the vents serve as another example of the amazing accuracy of the Bible, and the intricate, intelligent design of the Creator of these present-day fountains of the deep.

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EROSION OF THE GRAND CANYON OF THE COLORADO RIVER
Part III—Review of the Possible Formation of Basins and Lakes on Colorado Plateau and Different Climatic Conditions in the Past

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Abstract

The possible formation of basins and lakes on the Colorado Plateau is discussed. The likelihood of different climatic conditions (more precipitation) in the past is explored. All of these factors are related to a post-Flood model of the formation of the Grand Canyon of the Colorado River.

Introduction

The antecedent Colorado River hypothesis in relation to the formation of the Grand Canyon was presented in Part I (Williams, Meyer and Wolfrom, 1991, pp. 92-98). Also the postulation was offered that the major cause in the formation of the Canyon was the erosive work of large quantities of rapidly-moving water laden with abrasive matter in a relatively short time span. The river capture and ancestral river hypotheses were discussed in Part II (Williams, Meyer and Wolfrom, 1992, pp. 138-145). Also piping on a large scale as a mechanism of formation of the Grand Canyon was reviewed.

The possible formation of vast basins and lakes on the Colorado Plateau is explored in this paper. Also the possibility of a more moist climate in the past is considered. These conditions, coupled with the possi-

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