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HEAVY METAL ACCUMULATION IN RIVER SEDIMENTS—RESPONSE TO ENVIRONMENTAL POLLUTION

As evidenced by catastrophic cadmium and mercury poisonings in Japan, heavy metals belong to the most toxic environmental pollutants. Through the investigation of sediments, the extent, distribution, and provenance of heavy-metal contamination in rivers and lakes can be determined and traced.

Eight heavy metals (Cd, Hg, Pb, Zn, Cu, Cr, Ni, Co) in the clay fraction of sediments from major rivers within the Federal Republic of Germany (Rhine, Danube, Ems, Weser, Elbe) were determined by means of atomic adsorption spectrometry. The addition of the eight metals results in average values higher than 1,000 ppm for each river; in the Elberand Weser over 2,000 ppm are found. The zinc concentration in each river is higher than the other seven heavy metals together.

Heavy metals known for their high toxicity are most enriched—mercury, lead, and zinc by a factor of 10; cadmium by a factor of 50—compared with the natural background of these elements.

A geochemical reconnaissance survey on extreme cadmium concentrations in the sediments of the Neckar river (tributary of the Rhine) led to (a) the detection of extreme cadmium concentrations in the river water, (b) the detection of fish highly polluted with cadmium, and (c) the discovery of the source of the cadmium: a factory producing cadmium pigments.

The potential danger of the heavy-metal accumulation in river sediments lies in the possibility that, under certain circumstances (changes in eH-pH within the sediment), a dissolution or desorption might lead to a release of metals into the river water.

The mobilization of heavy metals from the suspended load and from the sediments—as is observed in rivers approaching the marine environment—could endanger marine organisms, thus negatively influencing the aquatic food chain.

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RECENT INORGANIC NONMARINE CARBONATE ENVIRONMENTS

Compared with modern carbonate environments associated with or derived from the marine milieu, the study of nonmarine carbonate depositional environments has been neglected, although these offer a much wider range of conditions under which carbonate formation and diagenesis can occur.

During the past years I have studied the following environments: (1) lakes and ponds, (2) springs and rivers, (3) caves (speleothems), (4) soils (especially caliche), and (5) technical incrustations (scale). My investigations clearly reveal that the formation of primary carbonate minerals (calcite, high-magnesium calcite, aragonite, hydrous magnesium carbonates) and of secondary carbonates (dolomite, huntite, and magnesite) in these various environments having different hydrochemistry, salinity, climatic conditions, etc., is mainly dependent on the Mg/Ca ratio of the solution in which the formation or transformation occurs.

By loss or extraction of carbon dioxide, evaporation concentration or mixing of different water bodies, calcite, high-magnesium calcite, aragonite, and hydrous magnesium carbonates precipitate in an order of increasing Mg/Ca ratios.

Dolomite formation takes place only at elevated

Mg/Ca ratios (> 7) if high-magnesium calcite is available. The reactions leading to the formation of huntite and magnesite at very high (> 30) Mg/Ca ratios are not fully understood; from observations in Turkish lakes, it seems evident that dolomite is the precursor of huntite and huntite is the precursor of magnesite.

A comparison between inorganic carbonate minerals deposited in the marine and nonmarine environments shows that the only significant difference in carbonate mineralogy is that (low-magnesium) calcite does not form under marine (or marine-derived) conditions. The explanation is that the high Mg/Ca ratio of the seawater (about 5) does not allow the formation of (low-magnesium) calcite.

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STAGES OF TRANSFORMATION OF CARBONATE SANDS INTO LIMESTONE AND DOLOSTONE: FUERTEVENTURA, CANARY ISLANDS

The island of Fuerteventura offers a unique possibility for studying mineralogical, chemical, and textural changes in Holocene and Pleistocene skeletal carbonate sands which, due to eustatic sea level changes, have been exposed to one or more diagenetic environments. An example is the diagenetic development of a 30,000-year old dolomitized calcarenite from the Jandia Peninsula.

Stage 1 (intertidal or beachrock stage)—Precipitation of magnesian calcite leads to the formation of beachrock in the intertidal zone.

Stage 2 (supratidal marine evaporitic stage)—Lowering of the sea level (about 2–3 m compared with stage 1) has exposed the beachrock to the supratidal zone which, however, still remains under the influence of the sea and of the evaporating seawater. After the retreat of heavy seas, seawater accumulated on the surface or within the pores of the beachrock evaporates and percolates through the calcarenite. The high Mg/Ca ratio (> 15) of the percolating brines causes dolomitization of the magnesian calcite cement as well as of allochems consisting of the same mineral (red algae, echinoderms).

Stage 3 (supratidal meteoric stage)—When, by further lowering of the sea level, the partly dolomitized beachrock is exposed to meteoric (freshwater) conditions, the supratidal meteoric stage is achieved. Aragonite of the allochems is converted to calcite by wet transformation and calcite is precipitated in the interstitial spaces of the calcarenite as second-generation cement (cement B).

Other interesting examples are calcarenites (eolianites) which originally were exposed to the meteoric diagenetic environment and are now in the intertidal zone; a first-generation cement consisting of calcite is followed by a second-generation cement consisting of magnesian calcite!

Calcarenites overlain by basaltic lavas permit the study of hydrothermal alteration of carbonate rocks.

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APPLICATION OF PLATE TECTONICS TO PETROLEUM EXPLORATION AT CONTINENTAL MARGINS

Approximately 90% of known reserves of oil and gas has accumulated within the past 250 million years, concurrent with formation of the present ocean basins, island ridges, and linear mountain chains of Andean and Alpine types. Concepts of crustal rifting, sea-floor

spreading, and plate tectonics help explain these tectonic features of the earth and may help locate additional reserves of petroleum, particularly along the present continental margins.

Differential extension of the lithosphere may result in high temperatures in the upper continental crust concurrent with local accumulations of shallow-water sands, carbonate rocks, euxinic muds, evaporites, and volcanic rocks. Where the lithosphere rifts apart, seawater encroaches and the asthenosphere wells up in the formation of oceanic crust. During continued divergence of the continents, this new crust subsides as it cools and moves away from the rifts, downwarping with it the thinned edges of rifted continental crust. Remnants of tear faults on the rifted continental blocks, and the presence of volcanic rocks and salt diapirs may be clues to petroleum provinces buried beneath the detrital continental rises and/or carbonate platforms that characterize such divergent margins.

Convergence of crustal plate margins (marked by oceanic trenches, linear trends of deep focus earthquakes, volcanic island ridges, and linear mountain chains) results in dominance of detrital over carbonate sedimentation, abrupt facies changes, locally rapid burial of deep water pelagic sediment with thick turbidites, shale diapirs, and layered sediment structures related to drape over differentially uplifted basement blocks, all on the trench side of volcanic island ridges and linear mountains. High temperature may accelerate the generation of petroleum on the continent side of such island ridges and mountains. Strike-slip displacements between adjacent crustal plates, combined with rifting or convergence, may explain other patterns of sedimentation, structure, and geothermal trends related to accumulations of oil and gas.

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EXPLORATION, GEOLOGY, AND POTENTIAL OF THE NORTH SEA

North Sea exploration was triggered by the discovery of the giant Slochteren gas field in northeastern Holland in 1959. Once the international boundary lines on the continental shelf were ratified according to the premises of the Geneva Convention, the stage was set for intense exploration. Initially, exploration activities were concentrated in the southern United Kingdom basin where gas discoveries were made in the Permian Rotliegendes sandstone, underlying the Zechstein evaporites. It was the presence of the evaporites which had a great effect on the course of exploration. They formed an efficient caprock for Permian dolomites and sandstones, but also created seismic velocity problems which confused structural interpretations. Additionally, salt acted as the medium for structural deformation of the younger sediments, a factor which was to prove to be very important in the Northern Tertiary basin, particularly in the Ekofisk area.

After the discovery of the Permian Rotliegendes and Triassic Bunter gas reservoirs in the United Kingdom sector of the North Sea, there followed a series of dry holes which led to a period of discouragement. However, discovery of the Cod gas-condensate field in the Paleocene sands and the Ekofisk oil field in Danian carbonate rock, both in the Northern Tertiary basin, revitalized the exploration drive and opened the possibilities of new reservoirs and an oil province on the north. The Ekofisk discovery was followed by additional discoveries in adjacent blocks, outlining the first giant oil field in northwestern Europe. A development

program is now under way with the ultimate aim of producing 1 million bbl of oil and more than 1 Bcf of gas per day.

A third exploration phase is now developing, following recent discoveries in the far north of the United Kingdom off the coast of Scotland. Oil potential is in Jurassic and perhaps older sandstones. In this area, water depths are nearly 500 ft, and production demands the development of new techniques.

Located in an area of increasing energy demand, North Sea oil production nevertheless is not expected to make a great impression on European energy supply problems. Although the North Sea may produce 3-5 million bbl of oil per day by 1980, by that date Western European oil consumption will have increased between 14 and 30 million bbl per day.

MEMBERSHIP AND CERTIFICATION

MEMBERSHIP APPLICATIONS

APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma 74101. (Names of sponsors are placed in parentheses.)

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