Utilization of Spores in Evaporite Studies

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ABSTRACT

Many salt rocks contain fossil plant spores in a good state of preservation and in large quantity. White and grey rock salt; salt clay of green, grey or black colour; and occasionally sulfates can be used for analysis. The concentration of spores in rock salt is as low as about 50 to 2,000 grains per cubic centimeter, but in salt clay of the same unit may be as high as 100,000 grains per cubic centimeter. The palynological investigation method is based upon the knowledge of spores which have been transported over long distances, equally distributed in the air, and blown over the original salt-forming basins. The key to stratigraphic interpretation is the fact, that each geologic period produced a different, significant microfloral assemblage. Salt spores prove to be of regional value because no local pollen rain, as in coal swamps, could significantly influence the uniform mixture of long distance pollen assemblages. The preservation of spores is influenced by the chemical composition of the embedding medium. Sodium chloride-rich units such as rock salt and salt clay contain spores with a high degree of carbonisation of the coat (exine) and in special cases in which even the fossil nucleus of the cell is present. Spores from dolomitic clay or sulfates do not show any nucleus-like inclusions; the carbonisation can be less as is indicated by the colour and very often different degrees of corrosion can be encountered. With this basic knowledge a number of problems in saline geology can be approached, such as dating of diapiric salt, reworking and resedimentation, primary deposition, and correlation of borehole samples of rock salt where salt layers of different geologic ages occur in the same section. And last but not least spores have been used to trace sources of undergroundwater entering a mine.

GENERAL ASPECTS

Chronologic relationships between many sediments are based upon microfossils such as ostracods, forams or conodonts. But in rock salt and other related evaporitic sediments, these reliable zone markers are almost entirely absent. Apparently the brine was not receptive to such anima life during the saturation process. But those organic particles distributed by *wind* over the evaporite basins are excellently preserved in a salt producing environment. The residue consists mainly o pollen grains and spores. They are produced ir large quantities in the surrounding forests, airborr over long distances, equally distributed over area of sedimentation, and deposited in the brine. Th immediate contact with a gradually saturating solu tion containing a certain amount of halogens pro tects the living spore cell from oxidation as well a from bacterial and fungal life activities; this cause such an excellent preservation that, in addition t the spore coat with all details, in some cases eve the nucleus of the cell can be found.

To select samples for spore analyses, one shoul observe colour, crystallisation, and the amount o carbonate, clay and sulfuric components. Suitabl is white to grey rock salt (not recrystallised) an black, grey or grey-green salt clay. Red and yello salt rocks do not contain spores. If possibl sulfuric components should be avoided as well a dolomite and limestone. It is interesting to not that tectonic activity in a diapir does only sligh damage to spores. A greater degree of fragmentation and carbonisation can be observed sometimes, but spores remain still determinable.

The quantity of material which is needed for one analysis preparation is about one kilogram of rock salt or about 10 to 50 grams of clay.

Preparation techniques in general follow the usual procedure in palynology, except in pure salt in which the dissolution is started by distilled water circulated around the rock sample. After careful bleaching spores are ready for microscopic investigation at magnification of 500 to 1,000.

STRATIGRAPHY

Palynological age determination is based upon the knowledge of pronounced changes in plant evolution during the past. Beginning with approximately Silurian time, throughout the remainder of the Paleozoic, and during the whole of the Mesozoic Tertiary, and Quaternary, we find characteristic assemblages of land plants. In that respect spore stratigraphy of evaporites is much the same as in other sediments such as clay or coal. But as experience demonstrates, a few additional features deserve close attention when using spores for salt stratigraphy.

First to mention is the fact that our well established scheme of spore stratigraphy is mainly based on sediments like coal which was deposited in a humid environment. But it is quite clear that we cannot expect elements of a swamp flora in salt samples. It was thus necessary to establish a spore sequence based on samples from an arid or noncoaly environment.

A second important consideration in the determination of stratigraphic relationships is that of reworking and resedimentation in salt deposits. Many samples so far investigated in Europe, especially from Alpine regions, contain a mixture of spores of different preservation and age. In micropaleontology it is common to consider the age of a sediment containing an assemblage with reworked fossils equivalent to that of the youngest component. Age determination of saline deposits, especially in diapirs, cannot follow that rule commonly. In many cases, diapiric salt is "coated" by younger sediments, shale or clay or sometimes even younger salt. During tectonic movement, when pressure causes plastic deformation of the salt, part of the coating layers can be worked into the diapiric salt in a greater or lesser degree. After preparation of such a sample, "older" and "younger" fossils occur together in the same slide and it becomes a problem to decide from which component the age of the salt should be determined. In such cases, an investigation of

PRESERVATION

may contribute to the solution of the problem. Spores embedded in salt-rich sediments show a relatively greater degree of carbonisation of the exine then those of other sediments. The colour prior to bleaching by chemicals is black in Paleozoic and black-brown in Mesozoic spores. Spores associated with dolomitic shales, sulfates and carbonatic material tend more toward a yellow colour and often show the effects of corrosion. For the first check for reworked material it is necessary to leave the spores untouched by oxydants and bleaching chemicals. Infrared light facilitates observation and determination of unbleached material.

Another preservation feature may also aid in the determination of the environment in which spores were deposited. In rock salt samples or sediments influenced by halogens, the preservation is so excellent that even the ancient nucleus of the cell is preserved. The colour of the fossil is dark brown like the spore coat after a short bleaching. Experience has proved that this colour is not restricted to a certain plant species or to spores of a certain geologic age. Permian, Triassic and Tertiary salt samples from different parts of the world contain spores with nucleus-like inclusions, and in younger salt we also find such features originating from both gymnosperms and angiosperms. In other words, the reason for such extraordinary preservation of spores apparently is the salty depositional environment. Humic acids in peat and coal—for comparison—do not permit a nucleus preservation.

A few investigations of spores in potash salts show an extreme contraction of the whole living cell, resembling the result of dehydration.

It could be concluded that (1) high coalification of a spore membrane, (2) nucleus like inclusions, or (3) extreme contraction are typical features of spores initially deposited in, or in the vicinity of, salt deposits. The features mentioned can partly be attributed to the influence of bromine.

The yellow colour of other preserved spores, mixed in the original population, indicates the age of the coating rocks which are worked in during deformation.

ENVIRONMENT

In addition to stratigraphic relationships, environmental conditions during deposition of salt can be interpreted. The botanical determination of pollen grains and spores gives some hints about the composition of forests. To reconstruct density and distance of flora, the absolute number of grains per unit volume of sediment (1 cc) should be calculated. Rock salt itself has a very low spore density, about 50 to 2,000 grains per unit, and in extreme cases as few as 10 grains have been observed. Such a low density speaks for sedimentation far from shore or distant from a vegetation belt, or it means rapid deposition. However, salt clay generally contains in the range of 3,000 to 50,000 grains and in some rare cases 100,000 spores per cubic centimeter have been encountered. These figures reach values equivalent to those of a peat deposit where a very local dense flora grows in the immediate vicinity.

APPLICATION

A few illustrations may demonstrate the utility of fossil spores in connection with the investigation of saline deposits.

Age determination.

Salt deposits in Austria are located at the border of the northern limestone zones of the East Alps. At Hallstatt the mining activities extend back more than 2,000 years. The age of the salt has been the subject of numerous discussions for more than a hundred years and opinions range from Permian through Lower, Middle, and Upper Triassic, to Liassic. The spores proved to be of the same age as the German Zechsteinsalt—in other words—Late Permian (Klaus, 1953, 1965). Recently Holser and Kaplan (1966) included in their sulfur isotope research program a study of two samples from Hallstatt. The results indicated quite clearly the Late Permian age of the salt deposit. Palynological age determinations have been carried out—among others—from Iranian Tertiary salt, some German Triassic and Jurassic deposits, and Tertiary/Quaternary salt from Israel.

Control of mining.

Alpine salt deposits mainly consist of a mixture of salt, clay, anhydrite, and large limestone inclusions. Salt and clay is of Late Permian age, the "coat" and large marl and limestone inclusions mainly of Late Triassic and Jurassic age. The latter are of such dimensions, that their penetration for mining purposes is not advisable. Howev Permian clays which are in many cases of the sa colour and petrologic character are much thinr and a part of the salt sequence itself, and a mi can be put forward easily. As soon as any clay marl is met with during the mining operation spore analyses are carried out in order to determ whether the mining operation should be continu or stopped.

Age determination of borehole samples.

Many drillings for oil exploration penetr several salt beds of different geologic ages. In so areas drilling will be stopped as soon as the low most—for instance in the Zechstein basin Up Permian—salt of a diapir is reached. To identify of the different salt beds and eventually locate Permian, spore analysis is carried out on e borehole sample containing salt. In such ca smaller quantities than one kilogram must analysed. The same investigation carried out i number of different drillings in one area enal the geologist to correlate the various salt beds.

Water-source determination.

Underground water entering a salt mine cause considerable difficulty. The origin of water can be determined in some cases by sp analysis. Surface water contains numerous mod pollen grains which can be transported in the n for long distances.

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