Re: EM signals

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From: gresham (*Gresham3_at_cox−internet.com*)
Date: 11/14/04

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Date: Sat, 13 Nov 2004 22:20:58 −0600
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in article VA.0000025a.0a9a77ab@mynameplus1.demon.co.uk.invalid, Aidan Karley at aidan@mynameplus1.demon.co.uk.invalid wrote on 11/1/04 11:55 AM:

> In article <BDABBE9B.4BEC%Gresham3@cox−internet.com>, Gresham wrote:
>> The oil field may also be
>> related to the current since oil can be extracted from shale like
>> clay−oil−water plugs by electro osmosis.
>>
> References?
> I've never heard of this being done. But I've only been working
> in the oil business for 18 years now, so what would I know about it?
>
I found this in my files dated 1984.

IONIC TRANSPORT

J. G. McKelvey

The ultimate objective of this project is the development of a comprehensive, coherent theory describing subsurface transport phenomena. While this objective may appear somewhat esoteric, our immediate objectives are a better understanding of the circumstances surrounding the early migration of petroleum and how we may use this information in better planned exploration. Although we are still some distance from our ultimate objective, we have reached a point where some of our understanding can be incorporated in current exploration.

Our present understanding of primary migration suggests strongly that migration within and out of the formative shale is controlled by diagenetic changes within the shale. It is suggested that these diagenetic changes are brought about through ionic transport processes which involve both the shale and the adjacent sands. It should be pointed out that the theories expounded here diverge from current theories on primary migration at very basic level, and hence may be expected to have ramifications on other older, more established theories such as those concerned with fluid migration or thermal maturity.

Our concept of these subsurface processes involves a synthesis of ideas extracted from our knowledge of the mechanical, chemical, and electrical properties of shales. During the early compaction of sediments, simple water loss is the dominant process. This proceeds very rapidly to a point where hydraulic permeability is reduced to a diffusive process. Concurrent with this, the electrical conductivity has increased and electrical transport becomes the dominant process. This, then, initiates the diagenetic processes. Calcium ions, which were once the preferred clay exchange ion because of their high charge, are now rejected because of their low electrical mobility. This appears to be the key which controls the genesis of oil field brines, shale diagenesis, and primary migration of petroleum. Extension of this theory also offers insight into many other subsurface phenomena, such as the formation of cap rock, marly zones, fracture filling, and metasomatic processes in general.

The project title "Ionic Transport", as well as much of the theory contained within it, is a direct outgrowth of a series of studies conducted by the "Petrophysics" group at Gulf Research during the late 1940s and early 1950s. This group, under M. R. J. Wyllie, realized that the mechanical, chemical, and electrical properties of shales were not independent properties but rather a manifestation of "coupled phenomena". This realization was originally based on an understanding of the SP (self potential log) as being due to a "coupling" between electrical and chemical forces. By "coupling", we mean the spontaneous generation of a flow or force through the application of a non−conjugated force. The SP is thus due to the generation of an electrical force in response to an applied chemical force. It was also realized that this coupling was due to the ionic character of shales, and hence to "ionic transport". Although all shale transport phenomena are now considered to be coupled phenomena, not all can be considered as due to ionic transport. The title "ionic transport" survives as a reference to this fundamental shale characteristic.

In 1808,, a pioneer colloid chemist in Russia named Rous studied the conductance of electrical current by wet clay. To his amazement, he observed that imposing an electrical potential difference across the clay led not only to the expected flow of electricity but also to a pronounced flow of water toward the cathode. Since, on a priori grounds, a flow of water should be driven by a pressure head, Rous made the converse experiment: he applied hydrostatic pressure to the piece of clay and obtained a flow of electricity.

Rous's ingenious experiments were the first to demonstrate the existence of coupled phenomena. They proved that a flow may not only be driven by its directly conjugated force, but may also be coupled to other, non−conjugated forces. Thus the flow of electricity is evidently caused by an electromotive force, but it may be coupled to a hydrostatic pressure; and conversely, the volume flow of water may be coupled to an electrical force.

The experiments of Rous are also important to us in another way; they were performed using clay, the fundamental building block of shale, which is considered to be the origin of petroleum. It is considered strange that so little attention was paid these phenomena in the ensuing years.

The theoretical study of coupled phenomena was originally pioneered by Lord Kelvin (Thomson) in 1854. Kelvin's treatment of thermoelectricity was based on pseudo−themostatics, in which the process was split in two parts, reversible and irreversible. Kelvin considered that heat conductivity and electrical conductivity were both irreversible and thus could not be treated using conventional thermostatics. As a result, Kelvin considered only the reversible portion of thermoelectricity: the Thomson and Peltier heats.

In his famous treatise on sound, Lord Rayleigh used a set of equations that expressed, in an explicit manner, the linear dependence of all mechanical flows on all mechanical forces operating in a system. Onsager, in 1931, extended this concept to include all thermodynamic flows and forces. This extension effectively combined all the Phenomenological Laws (D'arcy's, Ohm's, Fick's, etc.) into one new law or set of equations.

Onsager's Law, however, suffers from several shortcomings. First, like all phenomenological laws, it is a law of nature and hence independent of any model; i.e., it cannot suggest a physical model for what we have seen in nature or through experimentation. Second, the coefficients of the Onsager equations, unlike the coefficients in the original laws, usually lack physical significance and are not amenable to experimental determination. The important feature of the Onsager equations is the fact that the matrix of the coefficients is symmetrical. This has the effect of reducing the number of independent experiments that are needed to fully characterize a given system since a number of the coefficients are equal.

In the early 1950s, K.S. Spiegler, of the Gulf Petrophysics group, developed a physical model for transport processes in shales. Spiegler' s model effectively handled the coupling phenomena, did not disagree with Onsager's Law, and could be cast in a form similar to the Onsager equations i.e. in the form of a symmetrical matrix. Since this was a physical model, Spiegler could make assumptions which had the effect of further reducing the number of required experiments. Furthermore, he was able to define and specify these experiments. Spiegler's model is based on a simple Newtonian "frictional" model; i.e., the drive forces on a particle are considered equal to the frictional forces on the same particle. For example, the hydraulic pressure that forces water through a shale is exactly balanced by the friction" between water and shale.

This rational approach to transport processes was widely acclaimed and utilized by workers in many diverse fields. Unfortunately this model was never applied to shales in their subsurface environment, possibly because of the enormity of the task. Our understanding of subsurface processes still relies on physical models derived and synthesized from a variety of available experiments.

Research in biological membranes is one field that has supplied a new understanding of shale transport processes. Kedem, in a study of "ultrafiltration", concluded that ionic transport could occur in a direction opposite to the applied pressure gradient. Kedem went on to postulate that, in a heterogeneous media, containing hydraulic pathways shunted by electrically conductive elements, circulating ionic current could exist. Her model is based on the role of the "streaming potential" in ultrafiltration This appears to be a fair description of shales, and an interpretation of our own ultrafiltration data, collected using clay plugs, fully supports this model.

One ramification of Kedem's model is the almost total rejection (by a shale) of divalent cations (e.g., Ca) when in the presence of fast univalent ions (e.g., H or Na). Experimental verification of this effect may be found in the literature. This, then, explains the occurrence of calcium oil field brines and the high bicarbonate content of certain Gulf Coast shales.

The circulating ionic current, induced by pressure gradients (or, more probably, by salinity gradients), has acted to dissolve calcite and has transported the calcium to adjacent sands. The only mechanism for the transport of anions in such a system, is advective transport by migrating water, and hence the bicarbonate collects in the shale.

This model for shale diagenesis is consistent with geologic observa− tions. Most calcium type brines also contain radium which is out of equilibrium with its parent. The short half life of radium precludes any great migrational distance, thus it must have originated in the adjacent shale. Calculations indicate that the migration must have been extremely rapid, suggesting an electrical process. The chemical similarity between calcium and radium also suggests that the same transport process operated in both cases. Using reported radium and calcium concentrations for Gulf Coast sands, we calculate that the process is sufficiently rapid to totally cement most sands in about one million years.

This same type of electrical process is probably responsible for the early migration of petroleum. One of the early studies at Gulf Research was concerned with the recovery of oil from compacted clay plugs. This was done in an attempt to duplicate the natural process. At that time,fluid transport was considered to be responsible for primary migration, but we were totally unable to recover even a small portion of the contained oil. In desperation, we did what Rous did; we applied an electric current and were amazed to find that the oil also migrated to the cathode. In these experiments, we were able to recover a considerable portion of the oil, frequently to 50%. These experiments also indicated that the velocity of the oil was greater than that of the water within the plug. In a natural environment, oil may also be moved by this electro−osmotic process.

We may speculate about the process that migrated the oil in our experiments. Certainly the plugs were over pressured; this was evident. If we recall that Gulf Coast sands show their greatest increase in calcium just above the over pressured zone, and that this corresponds to the zone of greatest oil production, then we may speculate further.

Sufficient for now, however, is the connection that may be drawn concerning the mechanism that transports calcium and that which migrated the oil. The calcium transport was considered to be due to the "streaming potential", while the oil was transported by "electro−osmosis". These two processes are known to be equivalent measures of the same shale parameters Saxen, in experiments similar to those of Rous, showed that there was correlation between the amount of water moved (per Faraday) in the electro−osmotic experiments and the voltage developed (per unit pressure) in the streaming potential experiments. Saxen reported his observations in 1892. Mazur and Overbeek later showed the relationship was of a very general character, independent of any model, and a direct consequence of Onsager's principle of reciprocity of irreversible phenomena. Thus there may be more than accident in the occurrence of high calcium brines in connection with oil deposits.

In summary then, we suggest that a high organic content is not the only test that should be applied to a shale to determine its source potential. There must also be sufficient calcium to accommodate the diagenesis and, we suspect, sufficient salt to initiate the process. We do not wish to imply that these are the only conditions which will result in primary migration; only that these conditions appear to apply to the Gulf Coast.

McKelvey, J. G.