Unified magneto-electrotelluri

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MAGNETO-ELECTROTELLURIC exploration (METE) is based on a unified theory that explains the mechanism of electrotelluric current generation by deposits of minerals susceptible of modifying the physico-chemical properties of the rock environment in which such deposits are found.

Mineral deposits measurable from the surface fall in the following general classes: hydrocarbons, certain metal sulfides, uranium roll-fronts, native metals, native sulfur, geothermal energy deposits associated with magmatic intrusions, and other possibilities not as yet fully recognized, especially in the oceans.

Depending on surface conditions, topography, and the type deposits sought, various field procedures and interpretation techniques are used, but they are all designed to measure the vertical electrotelluric current flux density and its polarity (or sign) at depths in close proximity to the sources of such electric currents. Hence, METE methods have a controlled depth of investigation which may be varied from the surface by the proper selection of the grid-mesh spacing of measurements.

Hydrocarbon exploration. Unquestionable evidence of the existence of vertical electrotelluric (ET) currents flowing downward over oil and gas fields may be ascertained by anyone by observing on electric logs of good quality the downward SP gradient, from positive to negative, within well-defined and thick shale sections overlaying oil and gas accumulations.

The best example of this vertical migration parameter (VMP), as it was originally named (1962) before its true meaning was discovered (1969), is best observed in the Graneros shale overlaying the D and J sands in the Denver-Julesburg basin.

An additional example is given in Fig. 1.

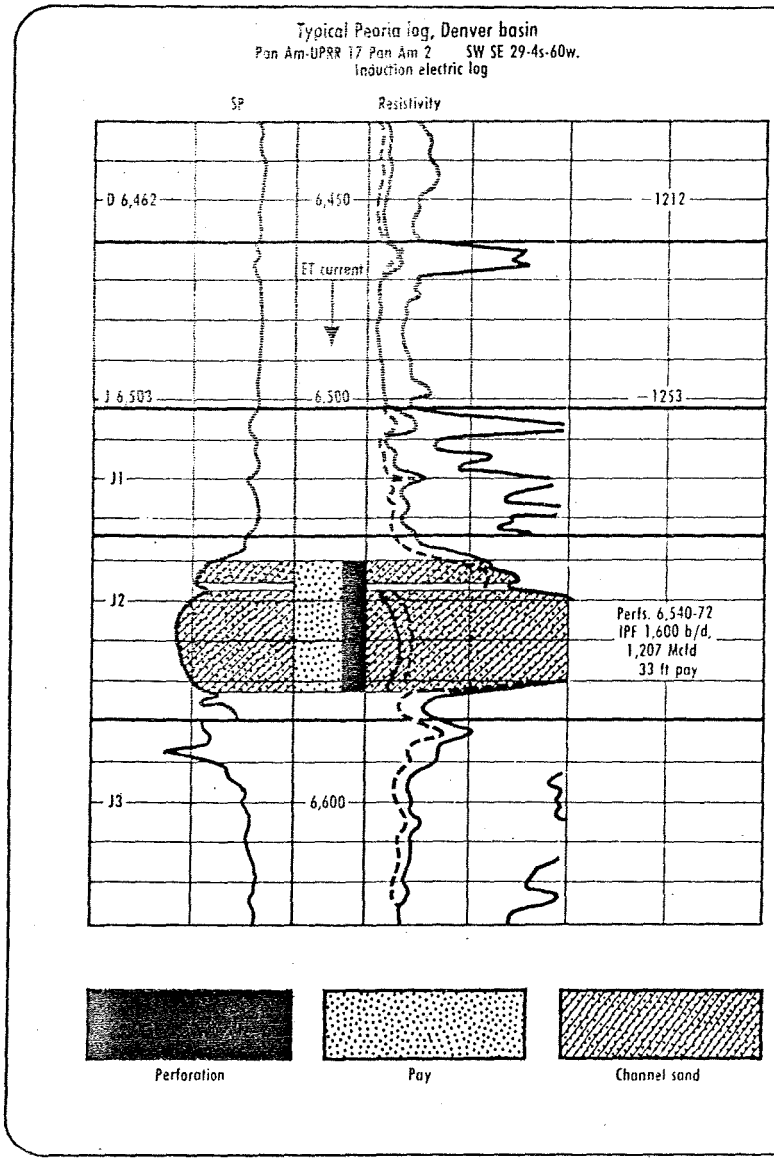
The writer has literally observed this VMP effect hundreds of times and cases of successful predictions of petroliferous trends have been published within which oil fields were thereafter discovered in the states of Florida, Alabama, Oklahoma, Colorado, and Wyoming.

Pirson and Gupta have carried out extensive laboratory investigations and they have established the source of hydrocarbon ET currents to be of a clay-catalytic-polymerization nature acting on the light hydrocarbon molecules yielding higher molecular weight hydrocarbons. In this series of reaction steps, electrons are released which render the rock environment electrically reduced, i.e., it has accepted electrons and its redox potential (Eh) is thereby lowered in value as compared to its original oxidized status when the reservoirs, as well as source rocks, were laid down in their aqueous environment.

Rock environments of different

Fig. 1

Example of "oil gradient" on SP curve



exploration method

redox potentials are therefore observed in the proximity of oil and gas fields, and especially in the form of "plumes" or "funnels" of reduced rocks that overlay the oil and gas accumulations, the edge of which corresponds to the limits of such accumulations.

Fig. 2 represents a hypothetical example of the stratigraphic oil and gas trap in a buried offshore sandbar and which generated ET currents according to the flow lines indicated. It has been established that there is a greater concentration of current lines (current flux density) as one approaches the surface of the earth. This is because the sedimentary geologic sections into which hydrocarbon entrapment is found are under a continuous process of compaction over geologic time, even though, for older rocks, this is at a very reduced rate compared to the initial rate when the original muds, oozes, and sands were originally laid out and at which time compaction was initiated at a rather rapid rate.

The continuous expulsion of formation waters "refuels" so to speak the oil and gas-field fuel cell" and as such compaction expelled waters are subjected to lower temperature and pressure in their upward motion, they release more hydrocarbons from solution thus maintaining a larger redox potential contrast at shallower depths where greater ET current flux densities are observed.

This condition prevails mostly where the oil-field fuel cell is approaching conditions of exhaustion, i.e., where active leakage of waters of compaction, and of their dissolved hydrocarbons, has substantially ceased at the level of accumulation.

This will be the case for accumulations in older reservoir rocks or as determined by other geological conditions.

For an oil and gas field still active and wherein the rate of water and hydrocarbon escape is in equilibrium at the "chimney" of reduced rocks with the rate of influx into the reservoir, then the vertical ET current flux density will be found substantially constant at any depth until the downward current projection reaches the level of the accumulation sought. This case has been recognized over the NW Norge field and the Manor prospect. For projections beyond this point, vertical current flux densities should disappear unless there are deeper accumulations.

A third case may be encountered; it is that of a young hydrocarbon accumulation perhaps by migration "en masse" of already pooled oil and gas and which, as a result of recent diastrophism or tectonic activity, has been set in migration from one reservoir to another and where vertical hydrocarbon leakage above the new entrapment locale is in the process of initiating reduced rock modifications. This situation will be recognized by an increase in the ET current flux density with depth.

This case is recognized in the Manda prospect.

Uranium exploration. METE surveys should find applications in finding uranium deposits which are found to the extent of 95% in sedimentary rocks in uranium roll-fronts such as represented in Fig. 3.

The horizontal variations in the form of Eh and pH profiles indicated within the ore body, are plotted along a cross section of the ore deposit (Shirley basin, Wyo.). Because of the redox potential contrast at the "roll front" between the unaltered and altered sandstones, ET currents will flow, as shown by arrows, along the flow lines within the ore body and in the overburden.

Measurements of the ohmic potential drop (according to Ohm's law) may be measured at the surface of the earth and the expected ET profile to be so measured is shown and will indicate a sharp potential drop, from positive over the oxidized zone to negative over the reduced zone. If extensive areal measurements are made over the roll front, it will be detected by a substantially linear and narrow region of steep potential gradients on an equipotential map. By processing

Fig. 2

Projective well-log interpretation

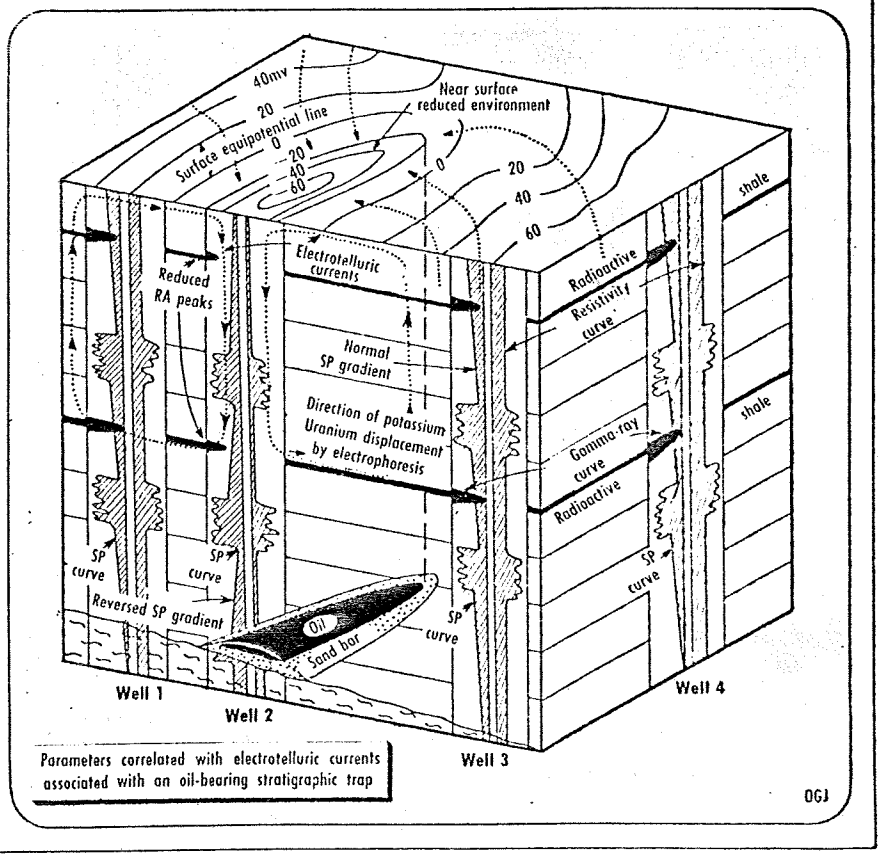
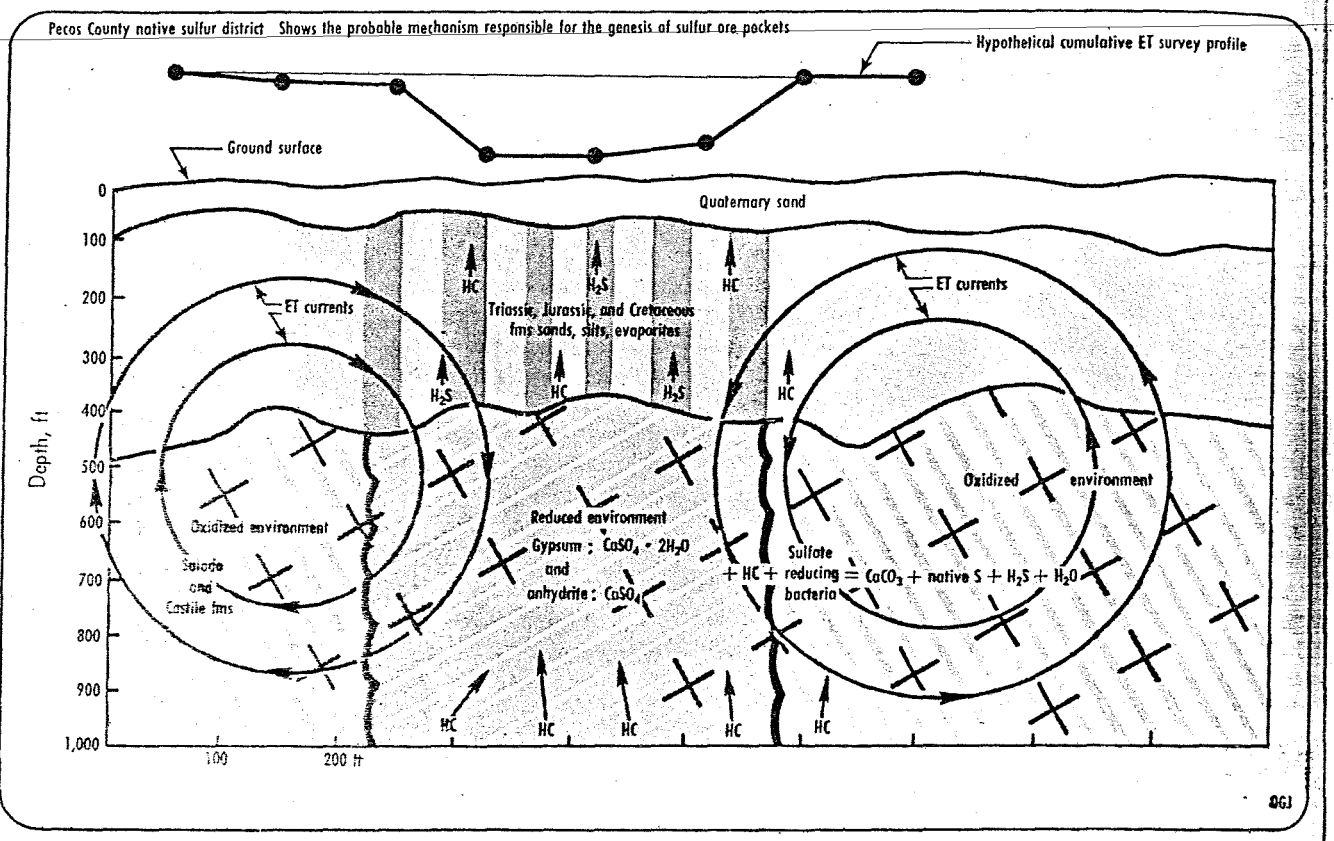


Fig. 3

Idealized geologic cross section



the surface measurements by means of the METE interpretation techniques, the vertical current flux density may be determined, mapped, and contoured at various depths of investigation to delineate the extent of the deposit.

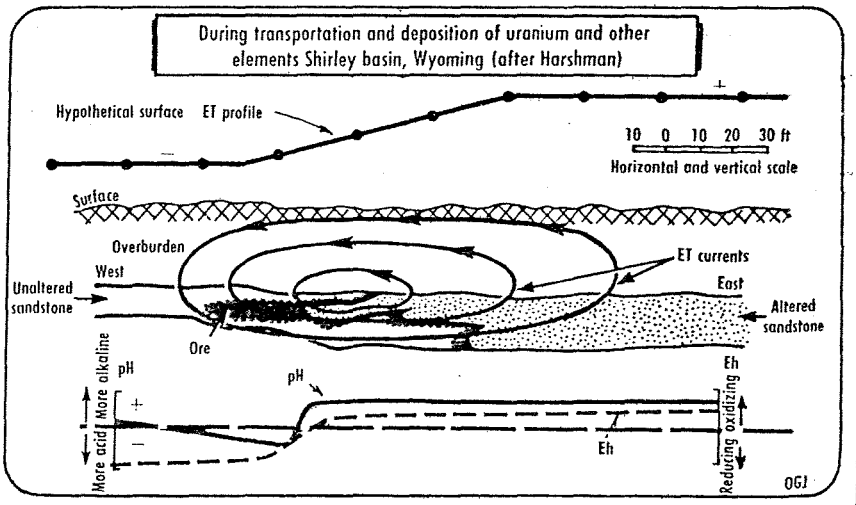
Native sulfur exploration. METE surveys should also find applications in the exploration for native sulfur in such areas as the evaporite sediments of the Delaware basin, West Texas.

Fig. 4 represents an idealized cross section through a hypothetical native sulfur district such as may be found in Pecos County, Tex. The generally accepted mechanism for the formation of native sulfur from gypsum and anhydrite is represented by a general chemical equation in Fig. 4 from which it is observed that hydrogen sulfide (H_2S) is released as gas, (a highly reducing agent).

In addition, it has been established that the sulfate reducing bacteria which are essential for the process of sulfur deposits generation, obtain their energy from upward-leaking hydrocarbons that escape through fractures and fissures from deeply buried oil and gas reservoirs. The combination of leaking hydrocarbons and H_2S creates a reduced rock environment where native sulfur is expected to be found.

Fig. 4

Postulated Eh and pH conditions



In the example represented in Fig. 4, reduced rocks are in close proximity to the unaltered Salado and Castille formations which are still in their original oxidized state.

Accordingly, ET currents will flow in the directions and give the distribution shown. Again, such currents may be mapped at the surface of the ground by the ohmic potential drop they create and the data may be processed so as to delineate the areal extent of the native sulfur pockets and thus determine the approximate depths at which the main sulfur-generating reactions are taking place.

END PART 1 OF 2 PARTS