ANOMALIES OF A SEASONAL THAWING ABOVE HYDROCARBON DEPOSITS

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ABSTRACT

While investigating permafrost for a group of gas fields of the Viluy hemisyncline, an unusually great difference between the largest values of the active layer thickness above the center of hydrocarbon deposits and those elsewhere was discovered. Minimal values of the seasonal thawing depth over all the area of gas fields are approximately equal. So, the expected influence of the exothermic reactions in the hydrocarbon deposit, as of a deep heat source, is the same over the entire area above the deposit. By this reason the observed anomalies of the seasonal thawing depth above hydrocarbon deposits exist due to the local surface heat sources. It is supposed that these are the result of exothermic reactions and activity of microorganisms in subsurface zones of the hydrocarbon dispersion halo.

Thermal fields in oil and gas bearing regions of the all world, as it follows from the results of numerous investigations, are characterized by the positive temperature anomalies above hydrocarbon deposits (Lialko, et al., 1979; Osadchiy, et al., 1976). There are many different views on the nature of the origin of these heat sources. Most investigators suppose that they are mainly the result of exothermic reactions in hydrocarbon deposits and in their dispersion haloes. It is noted in some cases that the displacement of the most enriched parts of deposits from anticline vaults is followed by the displacement of heat anomalies. Mehtiev and others (Mehtiev, et al., 1971) gives the results of the thermometric investigations above similar water and oil bearing structures and concludes, that the temperature on the same section is higher above oil deposits and this difference depends on the total supply of oil.These circumstances of the geothermometry of oil and gas deposits indicate a promising tool for oil and gas deposit prospecting. Perhaps it is more effective in the permafrost area as a zone of a difficult water exchange and, therefore, the underground water flow has less horizontal speed (Anzsiferov, 1971).

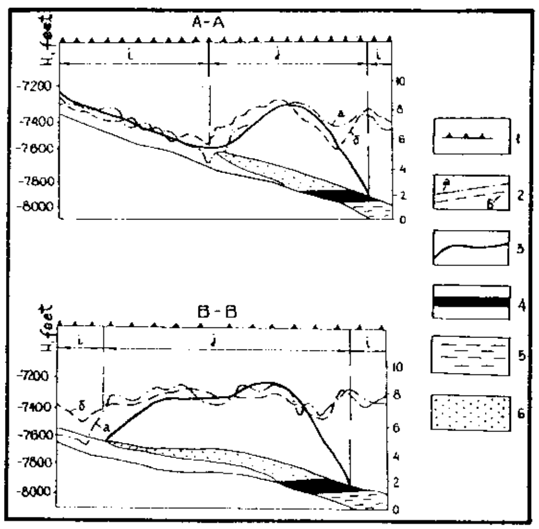

Fig. 1. Results of geothermic survey on the depth 1.4 m on two profiles across oil and gas deposit "Black Lake": 1 - the measurement points; 2 - the calculated heat parameter curves; 3 - the temperature graph; 4 - oil; 5 - water; 6 - gas; (i - the structural efficacy; j - the hydrocarbon deposit's efficacy).

In the permafrost areas with fresh subpermafrost waters, anomalies of the heat field above hydrocarbon deposits are expressed by the reduction of the frozen strata thickness which was noted for the first time at the end of the 1950 is (Diakonov, 1958; Ostriy, 1959; Ostriy, Cherkashin, 1960). The existence of such phenomena in some Viluy gas deposits shown in drilling data was discussed in papers (Baulin et al., 1970; Fotiev, et al., 1974). Later, we performed direct current soundings on the Nedzely, Tolon, and Mastah gas fields of the Viluy hemisyncline, using the experience of field thermal survey (Chekaliuk, et al., 1974), which takes into account the surface conditions and the heterogeneity of geological structure. We found that above the before mentioned gas deposits, the permafrost thickness reduction achieves hundreds of meters and this safely may be found by direct current sounding (Ahmetshin et al., 1989). The greatest reduction of the frozen strata thickness approximately matches the most productive parts of hydrocarbon deposits. So it becomes possible to do the direct prospecting of hydrocarbon deposit sthrough permafrost thickness anomalies to be found by using geoelectrical prospecting. This approach may be used in the area with fresh subpermafrost waters because in the case of saline subpermafrost waters, the thickness of the frozen strata and it's variations are determined by their salinity (Kalinin, 1976).

The area with the saline subpermafrost waters occupies the significant and most likely oil and gas deposits of Siberian platform (Hydrogeology..., 1970). Therefore attention is attracted to the circumstance that the heat field's anomalies above hydrocarbon and other mineral resources deposits are traced practically under the land surface (Anzsiferov, 1971; Lialko, et al., 1979; Osadchiy, et al., 1976; Chekaliuk, et al., 1974). For example, in figure 1 the results of geothermal investigations at the Black Lake oil and gas deposit (state Louisiana, USA) are given (Lasky, 1967). The temperature measurements were taken at a depth of 1,4 m. It is clearly seen that the higher values of temperature correspond to the deposit. According to the data in (Lialko, et al., 1979) the ground temperature above oil and gas deposits of the Dnieper - Don depression compared to background meanings may be $0{,}5^0$ C - $4{,}0^0$ C at the depth from 0 to 10 m.

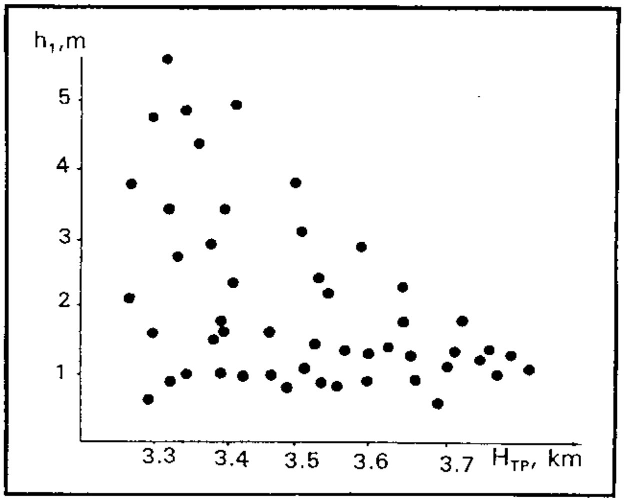

Fig. 2. The dependence of the active layer thickness (h_1) from the depth of the Triassic-Permian reflecting boundary (H_{TP}) on Mastah gas field (the loamy soil).

A perspective direction of geothermometry for oil and gas deposit prospecting is using the infrared survey to reveal heat anomalies due to the presence of hydrocarbons (see, for example, Vishnevsky, et al., 1978). The possibilities of the surface geothermal prospecting of oil and gas deposits are not completely clear yet. Therefore, let us note that geothermometry has been used in mapping thermal anomalies under snow cover (Krcmar, 1968) apparently due to hydrocarbons oxidation in its dispersion haloes. It is confirmed by the exposure in the snow cover of contrasting gas-biochemical anomalies above oil and gas deposits (Gas-bacteria..., 1981).

The available information, part of which was stated above, gives us reason to suppose that in the permafrost area thermal anomalies above hydrocarbon and some other mineral resources deposits may be a cause of seasonal thawing anomalies, which is a derivative of their heat regime. As far as we know this approach to solving some geological problems had never been discussed before.

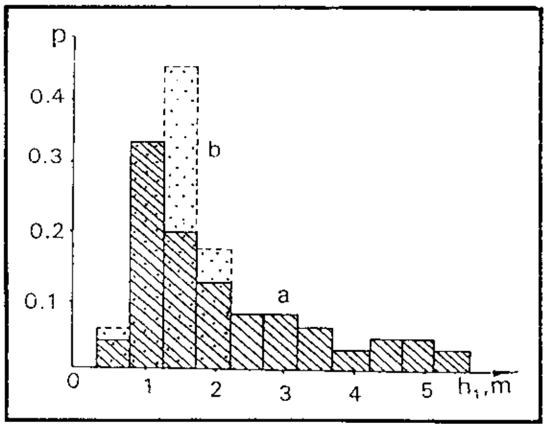

Fig. 3. The histograms of the active layer thickness (h) for the gas bearing (a) and none gas bearing (b) fields of the Hapchagay rise (the loamy soil).

The calculations of the frozen rocks temperature influence on the seasonal thawing depth show that it may be rather significant. For example, calculations of N.S.Lurje (Ershov, 1989) show that the fall of the average annual temperature of the ground by 1^0 C reduces the seasonal thawing depth in highly moisture-laden sands and loams on Yamal, Gydan and Tazov Peninsulas not less than by 0,1 m. L.S. Garagulya received similar results for the Lower Yenisei (Bady, 1987).

During our work by method of vertical electrical sounding (VES) on the Hapchagay rise of the Viluy hemisyncline, the seasonal thawing depth was also determined - by VES, by probing, where it was possible, and, on the Mastah deposit to control, by digging. The data received during the summertime were linked to the time of complete thawing (15 of September) with the help of adjacent meteorological stations data and to equal surface conditions. They are characterized by four types of landscapes: unfixed shifting sand ("tuculans"); pine forest on sand; mixed forest on sand; and larch forest on loam. The type of landscape in many cases determines the permafrost conditions. The average annual temperature of rocks is maximal on the sand and minimal in larch forests (the range of change is 0^0 - -4^0 C). On sand, the thickness of the frozen strata according to geothermic measurements can attain 450 - 500 m; under larch forests - 550 - 650 m or more. The temperature of the frozen strata on "tuculans" as a rule is constant and close to 0°C. There are taliks in upper parts of "tuculans", which freeze again on bogged up sites. Mineralization of the active layer waters do not exceed 0,1 g/l.

We received similar results on all investigated gas fields - Nedzely, Mastah, Tolon and Middle-Viluy - and therefore we shall restrict ourselves by bringing data for one of them - the Mastah deposit. The most part of Mastah field is covered by larch forest with predominately loam soils. The data on the active layer thickness as a function of the reflecting Triassic-Permian systems boundary depth is given in figure 2. It shows the following:

1) the largest values of the depth of seasonal thawing increase from 1,5 m outside the structure to 5 m (!) and more to the vaulting part, most enriched of hydrocarbons; 2) the dispersion of depth of seasonal thawing increases also to the center of the structure. So Mastah's structure is clearly distinguished by the anomalies of the largest values of depth of seasonal thawing and its dispersion. The comparison of the two histograms (fig. 3) shows that the active layer's thickness for one type of landscape on gas fields and outside them is essentially different not only by the largest values and dispersion, but by the law of the distribution: within the limits of the gas field, the active layer's thickness is distributed according the lognormal law; outside it - according the normal law (modules of the standardized skewness and kurtosis values for them simultaneously less than three).

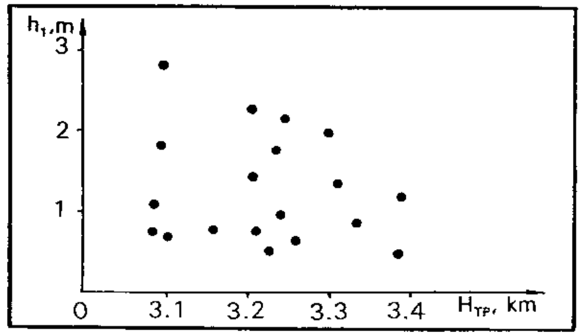

Fig. 4. The dependence of the active layer thickness (h_1) from the depth of the Triassic-Permian reflecting boundary (H_{TP}) on the Tolon gas field (the loamy soil).

It may be seen from figures 2 and 3 that the minimal values of the active layer's thickness at the contrary are approximately equal on this gas field area and outside it. So the thickness of the active layer increases not on the whole area of the gas field but only at the separate sites of it and more at the sites that are nearer to the vault of the structure and to the most productive part of it. It follows from this conclusion that the rise of the active layer's thickness above the gas deposit occurs due to separate surface heat sources. The contribution of a general deep heat source, causing the reduction of the permafrost thickness above a gas deposit, is all the same for its area or, perhaps, increases slightly to the center of it (fig. 4).

Surface heat sources can be the result of the exothermic reactions and the activity of microorganisms in the upper part of the hydrocarbons dispersion halo. The mosaic picture of the seasonal thawing and, therefore, the large dispersion of the active layer's thickness can be explained by uneven across the area over hydrocarbons due to their diffusion from deposit and by the diversity of the exothermic reactions and the activity of microorganisms proceeding conditions. For example, because of the difference in the content of oxygen in superpermafrost waters and so on. That corresponds with the results of geochemical research which ascertained the higher dispersion of hydrocarbons and carbonic acid content under soil above oil and gas deposits in comparison with their relatively even distribution outside ithem (see, for example, Hydrogeology..., 1970). Possibly, there exists a net accompanied by thermal anomalies and tectonic breaks, on separate parts of which fell some points of observations. But how to explain then the natural rise of the largest values of the active layer's thickness to the center of a deposit for all investigated gas fields?

The conditionality of the seasonal thawing anomalies by surface heat sources follows the very important conclusion that similar anomalies must take place in the area of the developing saline subpermafrost waters.

For the whole permafrost area the sites with saline superpermafrost waters may be a hindrance, but they can be easily detected and the salinity of these waters can be estimated and taken into account through the electrical conductivity of the thawed part of active layer.

The phenomena of the anomalously deep mosaic seasonal thawing and its anomalously high dispersion above investigated gas fields, especially, to all appearances, above the field's most productive parts, if it also exists in other oil and gas bearing provinces, can be used as one of criterions for the prospecting of oil and gas deposits of any kind in the permafrost area with subpermafrost waters of arbitrary mineralization. Using these data a preliminary estimation of vast territories can be made quickly.

A seasonal thawing is a summarized result of the external and internal heat sources influence during the time before the measurement. It is the inertial process, so the short-term fluctuations of the soil temperature according to meteorological conditions changes causing a great problem for geothermal survey, does not matter for the seasonal thawing anomalies mapping. But the time of the measurement and the type of landscape must be taken into account. Data on the seasonal thawing depth must be linked to the time of the complete thawing and must be examined for each type of landscape separately. They can be linked also to one type of landscape as was the case of the frozen rocks thickness analysis (Kalinin, Yakupov, 1976).

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