Introduction

Today hydrocarbons - oil and gas - are among the most important useful minerals. Gradual exhaustion of known hydrocarbon deposits makes the problem of prospecting for new ones more urgent. The area of prospecting is moving to new, relatively poorly investigated and almost inaccessible regions, in particular, the North. Simultaneously, prospecting of difficult-to-detect deposits, connected with rises of small amplitude, or of nontraditional types is necessary. These causes jointly make the prospecting of hydrocarbon deposits more expensive. Therefore it is very important to develop new approaches, which could allow the reduction of expenses at all stages of prospecting. This paper focuses on different possibilities for the direct prospecting of hydrocarbon deposits.

Heat anomalies attendant hydrocarbon deposits

Oil and gas deposits in many regions of the world are accompanied by positive temperature anomalies. It is believed that these anomalies are produced mainly by exothermic processes in hydrocarbon deposits. The results of geothermal investigations of similar water- and oil-bearing structures confirm that under otherwise equal conditions, temperature anomalies for oil deposits are more intensive and depend on the total oil volume present (Mekhtiev et al., 1971). An alternative hypothesis, which focuses on the heat flow through anticlines, explains only part of the observed effect. It is essential that temperature anomalies above hydrocarbon deposits are traced practically to the land surface (Lasky, 1967). It is logical to suppose that recognizable heat anomalies are produced by sufficiently large hydrocarbon deposits irrespective of their type and form.

Anomalies of permafrost thickness above hydrocarbon deposits

In permafrost regions with fresh subpermafrost waters, anomalies of the heat field are expressed by the reduction of permafrost thickness; this was first noted at the end of 1950’s (Diakonov, 1958). From a practical point of view, it was important to establish whether a search for such anomalies by electrical prospecting, required less work than drilling. For this purpose, direct current soundings were undertaken on the Nedzely, Tolon and Mastakh structures of the Hapchagay rampart. These structures are anticlinal folds from 25 to 40 km in length and 10 to 22 km in width, with amplitudes up to a few hundred meters. They are well outlined by the behavior of a seismic reflector on the Triassic and Permian systems boundary.

It was found that for the investigated gas deposits, in larch forests on loamy soils, the permafrost thickness reduction was up to hundreds of meters and this could be clearly determined by the electrical prospecting (Akhmetshin et al., 1989). Electrical soundings and isolines of permafrost thickness for the Mastakh gas field are shown in Figure 1. In Figure 2, permafrost thickness
Anomalies of active layer thickness above hydrocarbon deposits

In the course of direct current soundings, the active layer thickness was also determined (Yakupov and Akhmetshin, 1995). For the sake of brevity, here we present only the main results. The general picture is a mosaic: sites with large and small seasonal depths of thaw alternate. The greatest values of the active layer thickness increase on some sites from ~ 1.5 m outside the structure to 5 m and more over the central arch, the area most enriched by hydrocarbons (Figure 3). We believe that anomalous local increases of the active layer thickness are caused by separate, isolated, and uncoordinated surface heat sources. They can result from hydrocarbon oxidation in the upper part of the dispersion halo, mostly in the active layer, with consequent heat liberation. The large variance of seasonal thaw may be explained by the uneven flow of hydrocarbons coming to the surface because of their diffusion from a deposit, and the diversity of conditions for the exothermic reactions and the activity of microorganisms. This supports the results of geochemical research which showed a higher variance of hydrocarbons and carbonic acid content under soil above oil and gas deposits and a relatively more even distribution elsewhere (Babaev and Kemberda, 1987).

Minimum values of the active layer thickness are approximately equal over the entire gas field area or increase slightly near the center. So the contribution of a deep heat source to seasonal thawing is equal over all the hydrocarbon deposit area and apparently not large. The reduction of the permafrost thickness above hydrocarbon deposits may facilitate the diffusion of hydrocarbons to the surface.

The greatest reductions of the permafrost thickness approximately match the most productive parts of hydrocarbon deposits. However, the possibility for direct prospecting of hydrocarbon deposits is limited to areas with fresh subpermafrost waters. Where saline subpermafrost waters are present, the thickness of the frozen strata and its variation are determined by the salinity (Kalinin and Yakupov, 1989). Areas with fresh and saline subpermafrost waters can be distinguished by the existence or nonexistence of a correlation between permafrost thickness and subpermafrost horizon conductivity (Kalinin and Yakupov, 1989).
The active layer thickness on gas fields and outside of them is distributed accordingly to lognormal and normal laws. The phenomenon of unusually deep seasonal thawing within the mosaic pattern above hydrocarbon deposits can be used as a criterion for the direct prospecting of oil and gas deposits of any kind in the permafrost regions with subpermafrost waters of arbitrary mineralization. In some cases, sites with saline soils may be a hindrance, but they can be easily detected and taken into account through the electrical conductivity of the thawed part of the active layer.

A consideration of both permafrost thickness ($H$) and active layer thickness ($h$) jointly as a ratio ($h/H$) seems to be yet more informative (Figure 4). Anomalies of $h/H$ above hydrocarbon deposits are obviously greater than those for $H$ and $h$ separately since $h$ increases and $H$ is reduced in these areas.

The amount of work to determine (1) permafrost thickness and (2) active layer thickness differs greatly.

Operationally, the active layer thickness should be determined first for an area to be investigated, and then the permafrost thickness measured on any seasonal thaw anomaly using a sparse net, including sites beyond the anomaly to estimate the background value.

**Conclusion**

Hydrocarbon deposits are accompanied by anomalies of the upper and lower boundaries of permafrost. For sufficiently large deposits, anomalies of the active layer ($h$) and the permafrost thickness ($H$) can be outlined by electrical prospecting and this may be used for the direct prospecting of oil and gas deposits. In an area with fresh subpermafrost waters, anomalies of $h$, $H$ and $h/H$ can be used; in an area with saline subpermafrost waters, anomalies of $h$ are useful. While most hydrocarbon deposits are accompanied by anomalies of these types, similar anomalies may also be produced by other causes. For example, they can be indications of past changes in surface conditions. The probability of the accordance of hydrocarbon deposits with active layer anomalies is apparently higher, because it is difficult to imagine other sources of anomalies of such intensity and spatial pattern. The potential presence of saline soils can be easily detected and taken into account while surveying, by measuring soil electrical conductivity.

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**References**


