Tests on Application of Soil Magnetic and Integrated Gamma Ray TLD and TC Methods to the Exploration of Sandstone-Type Uranium Deposits

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Abstract This paper introduces the test results of the soil magnetic survey and the integrated gamma-ray TLD and TC methods for sandstone-type uranium exploration and describes the prospecting mechanism. The tests have proved that these approaches have yielded good results on classifying the sedimentary facies, defining the redox transitional zones and reflecting deep mineralization information. They may probably become new methods on searching for sandstone-type uranium deposits.

Key words: soil magnetism, gamma-ray thermoluminescence dosimetry, total count rate of gamma ray, sandstone-type uranium deposit

1 Introduction

China is one of the countries that have a large amount of uranium deposits of the sandstone type (Huang et al., 1981; Chen et al., 1983). Investigation of the sedimentary lithofacies of a basin, determination of the redox transitional zone and collection of the deep uranium mineralization information are of great importance in searching for hydrogenic sandstone-type uranium deposits. In order to solve the above-mentioned issues by using new and simple means of ground exploration, tests, including soil magnetic survey and integrated gamma-ray TLD (thermoluminescence dosimetry) and TC (total count rate of gamma ray) survey, were done in the Baolegentaohai depression (eastern region) and Onggon Ul depression (western region), the Eren basin, Inner Mongolia. In the study, relevant influencing factors were considered, and their effects were evaluated to ensure the survey results and the target information concerned.

2 A Brief Introduction to the Detection Mechanism

2.1 Mechanism of the magnetic survey method

During the diagenetic stage and the following geological processes, non-oxidized sediments enriched in organic matter will continue to produce gases with a reducing ability (e.g. H_2S, CO_2, CH_4 and N_2) owing to the inversion of organic matter. In a sedimentary basin, mainly because of the pressure of sedimentary loading, the gases produced from the argilloid layer will migrate into the adjacent clastic rocks layer, then along the updipping trend of the clastic rocks layer. At the places where the upper covering layer (argillaceous rocks) is thinning, pitching out or changing in facies or encounters a fault zone, the gases will mainly migrate vertically upwards. When encountering oxygenated groundwater, the gases will be gradually consumed. Thus, the movement of oxygenated groundwater infiltrated from the surface also plays an important controlling role in the distribution of the reduced gases.

In the zones where the underground gases migrate towards the near surface, the concentration of reducing gases in the soil surface increases remarkably. This geological phenomenon has been proved in oil and gas prospecting. A relatively reducing environment will be formed due to the relative concentration of reducing gases in the soil. Thus, a large amount of magnetic ferruginous materials will be retained in the soil and new magnetic minerals will probably be

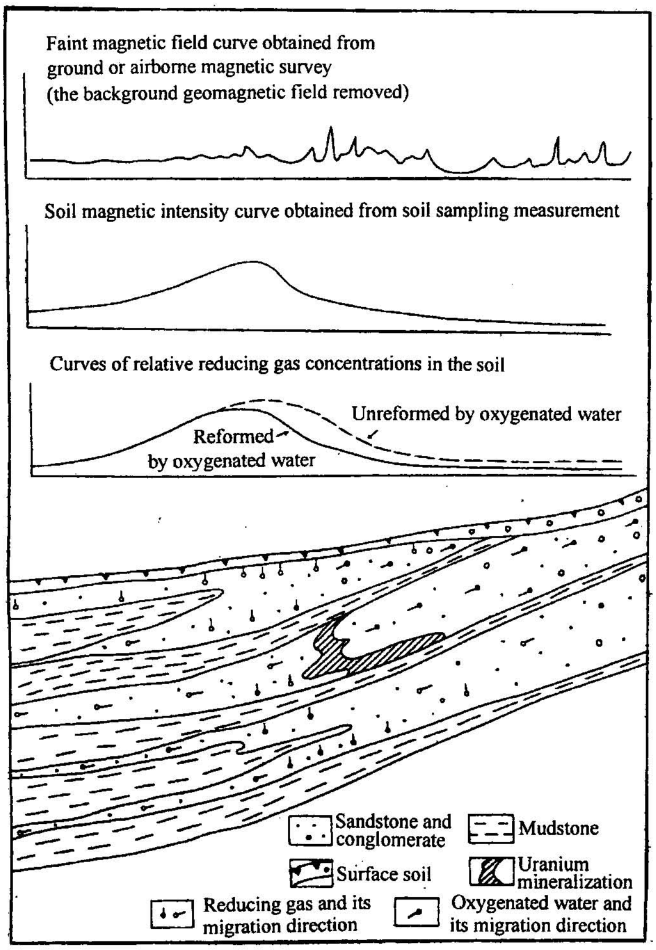

Fig. 1. Mechanism for faint magnetic anomalies in the soil.

formed. In addition, as the underground gases migrate towards the surface, magnetic particles would probably be brought too. All the above-mentioned factors may attribute to the increase of magnetism in the soil enriched in reducing gases (Fig. 1). Hence, through the measurement of soil magnetism we will be able to define the concentrated zones where the deep underground gases migrate towards the near surface, which will provide a valuable basis for determining the sedimentary facies and the range of oxidation by the oxygenated groundwater.

2.2 Mechanism of the integrated TLD-TC survey method

Using the integrated TLD-TC survey method may help eliminate the influence of the surficial sedimentary radiation field and collect the information coming from the deep underground.

The gamma-ray thermoluminescence dosimeters, which are buried at certain depths (usually 50 cm or so) in the soil, receive radiation from the following two sources: (a) contributions from the soil containing radioactive nuclides around the TLDs; (b) contributions from the radioactive nuclides migrating from the deep earth. The latter mainly come from the radon daughters, such as ^{214}Pb, ^{214}Bi and ^{210}Pb. Half of the gamma ray detected by the TC survey is the contribution from the surface within several centimetres. Owing to the rapid diffusion of radon at the interface between the air and the ground, the content of radon coming from the deep earth is far less in the thin layer of the surface than in the deeper soil. Meanwhile, as the starting threshold of ordinary ground gamma-ray surveying instruments is relatively high, the gamma ray coming from ^{210}Pb cannot be detected. Therefore, the ground gamma-ray surveying mainly reflects the radiation intensity of the soil itself. It can thus be seen that by using the integrated surveying method the value measured by TLD minus that by TC may reflect the information mainly coming from the deep. In short, with this simple method it may be able to eliminate the interference caused by the nonuniform radiation field of the soil itself, and highlight the weak but interesting information of the deep earth.

3 Test Results

3.1 Test results of the eastern region

The geological features of the Eren depression can be seen in the study of Lü Xiuxiang et al., 1996. The eastern region is situated from the southeast fringe to the centre of the Baolegentaoahai depression. The top layers are 30–90 m thick, which consist of Pliocene red argillite and are overlain by Lower Cretaceous sedimentary layers. In the peripheral zone the Lower Cretaceous is dominated by medium to coarse clastic rocks of alluvial fan facies, with a thickness of 500–1000 m. Its overlying sandstone layers have suffered phreatic oxidization to different degrees. In the central zone, lacustrine mela-argillite is dominant, with the thickness exceeding 1500 m. Prospective

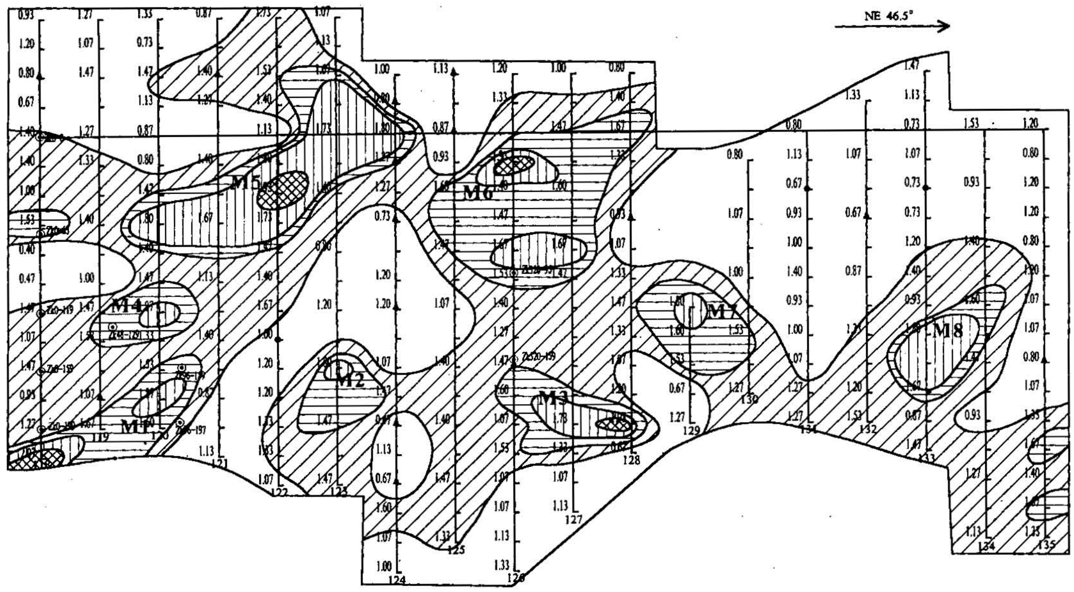

Fig. 2. Faint magnetic anomaly of soil in the eastern region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

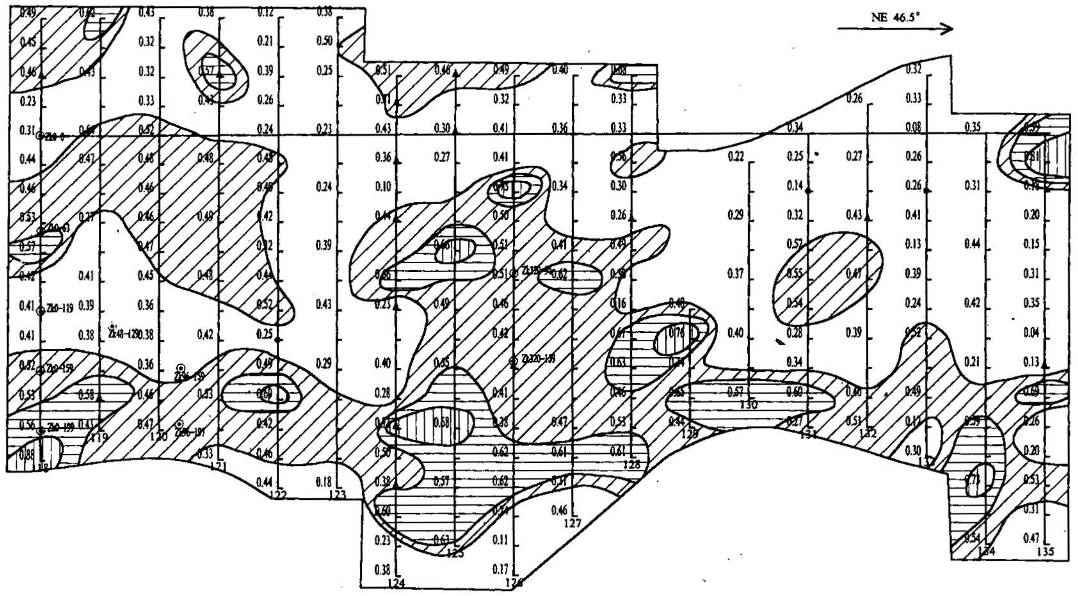

Fig. 3. γ thermoluminescence remanent intensity (△TLD) in the eastern region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

drilling for uranium deposits has been done in the depression.

Figure 2 shows the results of soil magnetism survey, in which the Nos. M4–M8 high value haloes lie in the front zone of the alluvial fans in arc shape, which coincide with the front of the phreatic oxidized zone that has been proved by drilling. All the ore holes (ZK0-259, ZK48-129, ZK96-197 and ZK320-95, with the thickness of the mineralized horizons ranging from 150 to 300 m) discovered by drilling lie on the south-east side of the arc-like high value halo zone, i.e. from the centre to the front of the fan. This shows that the variation of soil magnetism is indicative of the litho-facies and mineralized sections favourable for uranium deposits.

The formation of the other three high value haloes in the region is probably related to other factors, among which No. M3 has been proved by drilling to be related to an oil-gas pool and No. M1 may be related to a fractured structure.

Figure 3 shows the results of the integrated TLD-TC survey, and Fig. 4 gives the results of the single TLD. By comparing the two, we may notice the obvious difference. The high value haloes (△TLD) measured by the integrated survey are concentrated on the fringe of the depression, corresponding to the alluvial fans. The fronts of the haloes are also arc-shaped, and obviously match with the halo zones of No. M4–M8. All the ore holes are distributed within the high value halo zones (△TLD) or close to their fringes. The re-

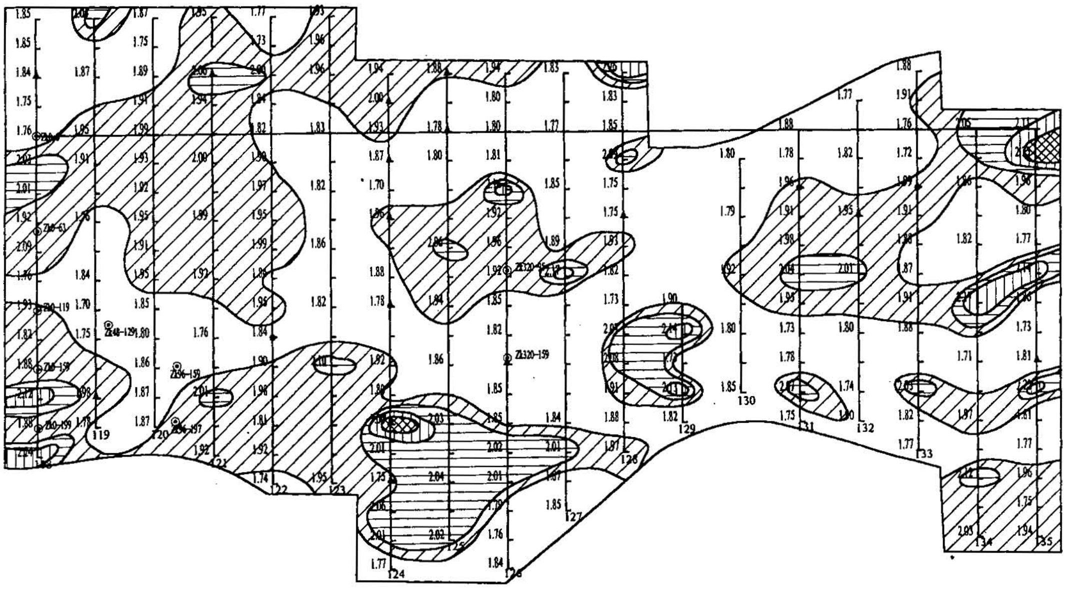

Fig. 4. γ thermoluminescence (TLD) intensity in the eastern region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

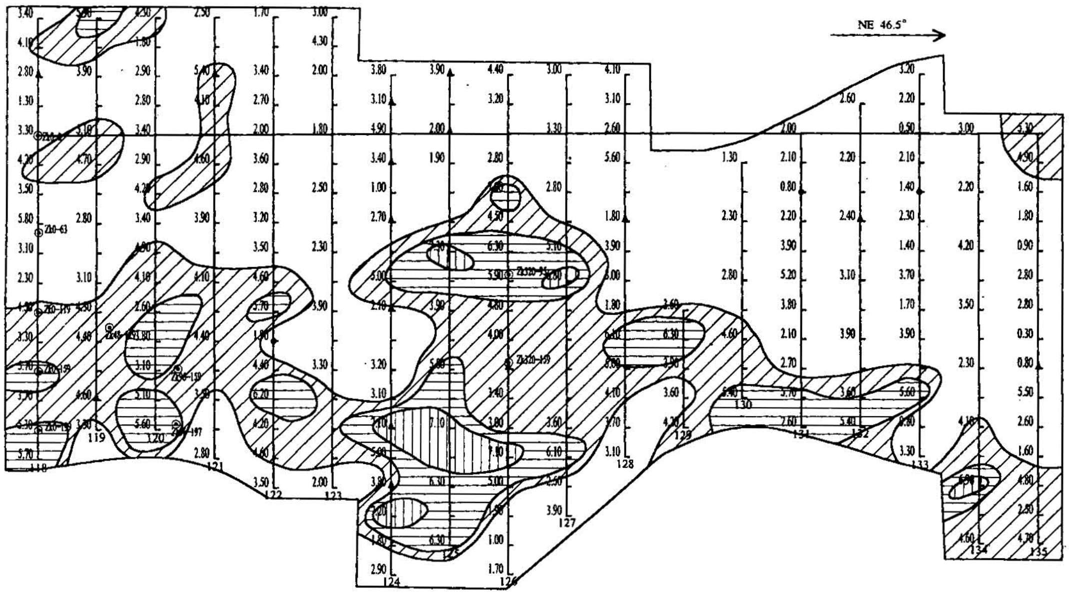

Fig. 5. Synthetic anomaly map of the γ thermoluminescence remanent intensity (△TLD) and soil magnetic intensity in the eastern region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

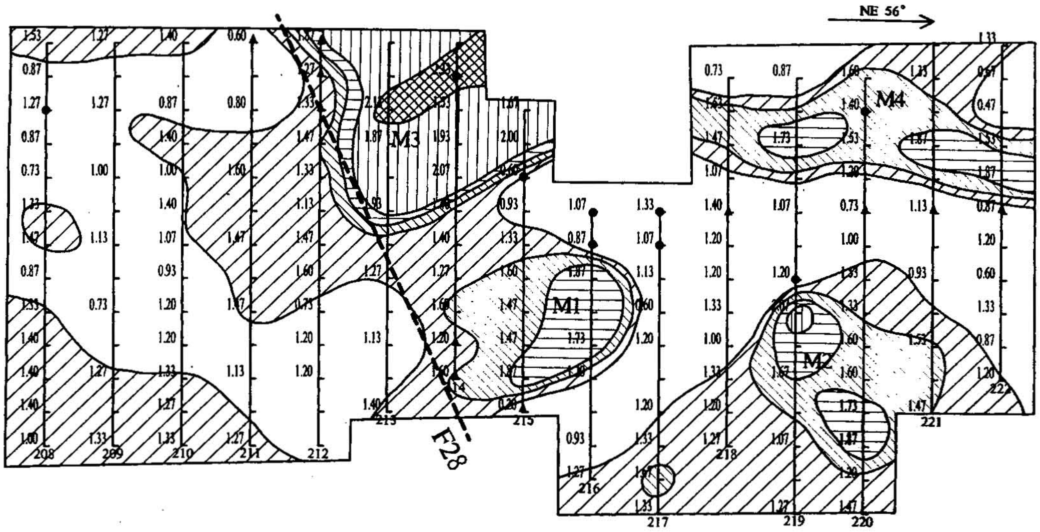

Fig. 6. Faint magnetic anomaly of soil in the western region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

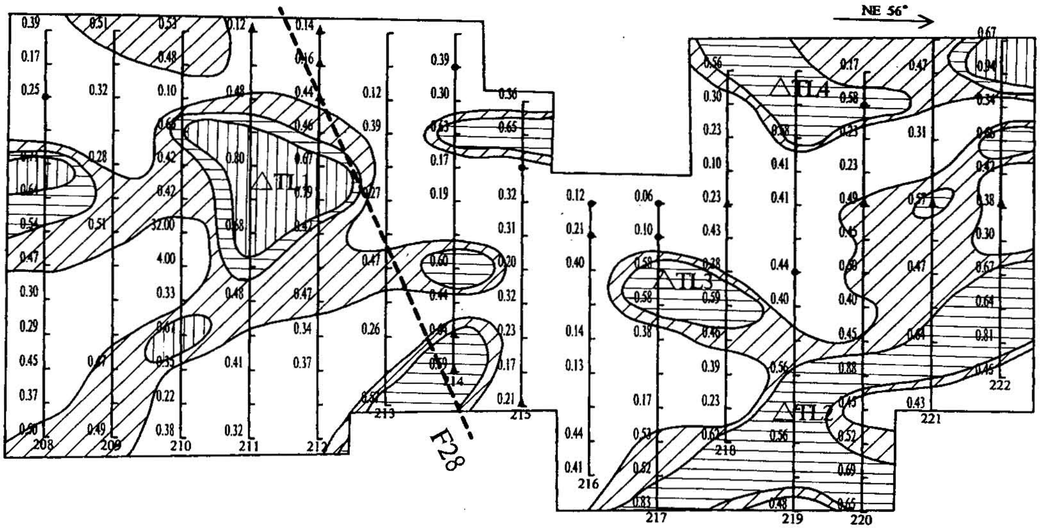

Fig. 7. γ thermoluminescence remanent intensity (△TLD) in the western region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

sults by combining △TLD and the information of soil magnetism (Fig. 5) show a better corresponding relationship to the uranium mineralization explored.

3.2 Test results of the western region

The western region is a sector of the Onggon Ul depression. The width of the depression is usually less than 10 km. The test region is divided into two sectors by the No. F28 fault inferred by the aero-magnetic survey: the maximum thickness of the sedimentary cover is about 1500 m in the northeast sector and less than 800 m in the southwest sector. Based on the development characteristics of the sedimentary cover in the region, it is inferred that the Lower Cretaceous layers in the southeast sector mainly consist of medium to coarse clasolite of river facies, and in the northeast sector relatively thick argillite of marsh facies or lacustrine facies may have been developed in addition to the river-facies clasolite. Meanwhile, based on analyses of the landform, vegetation and water content in the soil, the southwest sector belongs to a groundwater runoff area while the northeast sector is a discharge area.

The results of soil magnetic survey (Fig. 6) show that the variation of magnetism has an obvious zoning feature, i.e., all the high value haloes lie in the northeast sector. In the region near the fault F28, the field values are remarkably higher and the high value haloes do not cross the fault , which clearly shows that the soil magnetic variation of the region is related to the following three factors: (1) The fault F28. It has played the role of cutting off and dredging for the lateral migration and vertical migration of the underground reducing gases respectively. (2) Whether the lower layer can develop into a gas-productive layer (such as the mela-argillite) . (3) The groundwater activity. In the runoff zone of the southeast sector, the continuous supply of oxygenated groundwater will cause neutralization and consumption of the reducing gases, thereby weakening the magnetism of the surface soil.

Figure 7 shows the results of the integrated TLD-TC survey, in which the No. △TLD1 high value halo is the most significant anomaly, which is probably related to uranium mineralization of the old channel. The main basis consists of the following three aspects: (1) The halo lies in the runoff region of the southwest sector bounded by the fault F28, and its northeast boundary coincides well with the fault, which shows that its formation is obviously controlled by the runoff and discharge system. (2) The halo is composed of three zoned branches, among which the dominant one lies in the centre of the depression while the other two at the southeastern side extend to the fringe of the depression, corresponding to the modern valleys in the provenance area. Lying in a depositional environment of the river valley, the river channel deposits are better in sorting and permeability than other zones of the river valley. They may form uranium-enriched zones, which are also favourable zones in which radon migrates toward the surface. Therefore, the shape of the halo is probably related to the old channel. (3) The position of the highest field value of the halo is right adjacent to the No. M3 high value hålo, whose soil magnetism is the highest, which shows that the adjacent area should be the most significant part of the geochemical barrier. Therefore the top position of the No. △TLD1 high value halo is probably just the most favourable uranium-enriched zone. After integation of the △TLD and the magnetic information of soil (Fig. 8), the high value halo becomes more prominent.

4 Conclusion

The test results of the two regions show that the mag-

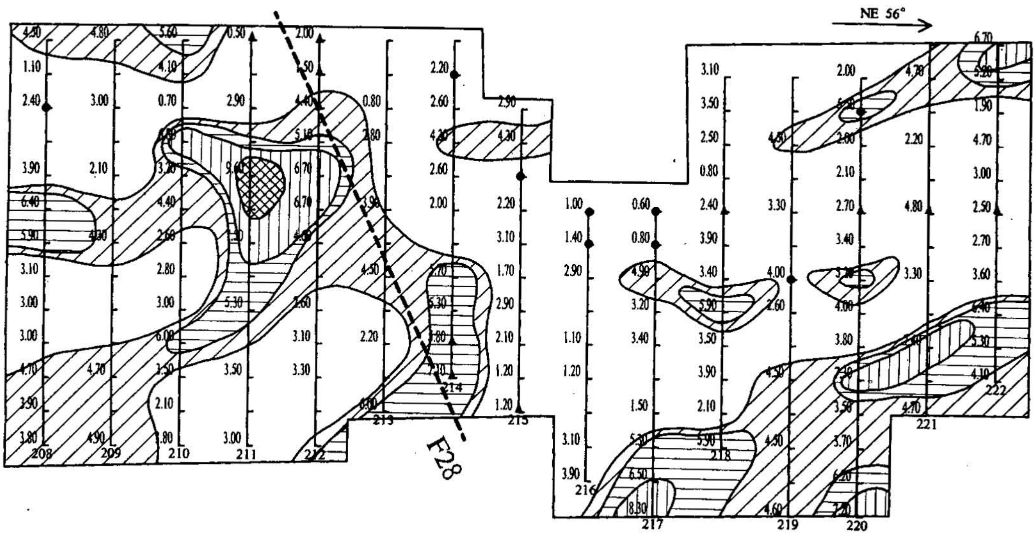

Fig. 8. Synthetic anomaly map of the γ thermoluminescence remanent intensity (△TLD) and soil magnetic intensity in the western region.

●–Grey-black clay; ▲–mainly sand. Samples from the unmarked sampling sites are red brown sandy soil.

netic variation of soil is related to a number of factors, including the lithological character and lithofacies of the deep sedimentary cover, the stratigraphic structure, the oxidization degree of rock strata and fractured structure, which may provide useful information diagnostic of the most favourable uranium metallogenetic segments. By using the TLD-TC survey we have acquired the deep radioactivity information as anticipated, which corresponds well with the results of drilling in the eastern region.

The application of the two methods mentioned above is only a test in the sandstone-type uranium exploration. Whether it has a general effect needs more practice.

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