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Natural electric fields in Siberian gold deposits: structure, origin, and relationship with gold orebodies

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Abstract

Characteristics of the constant natural electric field in the Siberian gold ore areas are given. The regularities of spatial variations in the electric-field potential and the parameters and properties of anomalies have been established. The cause of the natural electric field in deposits of major genotypes has been elucidated. It is shown that the electric field is induced mainly by physicochemical processes running in electron-conducting syn-ore metasomatites and by circulation of groundwaters. Orebodies do not influence significantly the structure of the observed electric fields. We give recommendations on application of the electric-field method at various gold ore objects.

Keywords: electrical prospecting; natural electric field; gold deposits; Siberia

Introduction

The self-potential (SP) method appeared in the geological practice in the first quarter of the 20th century and justly attracted the attention of both ore deposit prospectors and specialists in engineering and geological research. The peak of its use in Russia and abroad was in the second half of the 20th century. By that time, the physicomathematical and petrophysical basis of the method had been generally created, and the corresponding work practice and interpretation methods had been developed (Abdelrahman et al., 2006; Bigalke and Grabner, 1997; Ogil'vi, 1990; Ogil'vi et al., 1987; Parasnis, 1965; Revil and Jardani, 2013; Ryss, 1983; Semenov, 1974; Sveshnikov, 1967).

By now, a large amount of factual material has been accumulated owing to the results of the practical SP method application. These data permit one to determine the structure and origin of the natural fields and assess the method potentialities in real physicogeologic conditions during the exploration for a definite type of mineral resources or the solution of particular standard geological problems.

In this article, the above issues are considered with regard to gold deposits of the Siberian region.

Gold deposits are localized mostly in the folded framing of the southern and southeastern areas of the West Siberian Platform (Kuz'min et al., 1999). The natural electric field was first discovered by V.V. Borodin during the prospecting for gold deposits in West Sayan (Ol'khovka–Chibizhek gold ore district) in 1934.

Later, the SP method was widely applied at Siberian gold deposits (Chebakov and Roshchektaev, 2001; Erofeev et al., 2003; Krasnikov et al., 1967; Mozgolin, 1978; Narseev and Kurbanov, 1989; Nikiforov, 1945; Seifullin, 1965; Shatrov, 1979; Vovchenko, 1968a,b).

To date, geophysical SP surveys (usually on a scale of 1:25,000 and larger) have been made within most of the ore fields of large gold deposits and gold ore districts in the Sayans, Yenisei Ridge, Lena gold ore province, and gold ore provinces of southeastern Siberia.

Today, the SP method is often applied together with other geophysical methods during prospecting for gold (Saukov, 1975).

The data of long-term field measurements of the SP parameters in different gold ore provinces of Siberia testify both to the partial similarity of the electric fields of deposits and to their considerably different relationships with the products of ore-forming processes in the regional gold ore areas.

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The structure of the natural electric field and the parameters and origin of its anomalies

The amplitude of the SP anomalies at gold deposits usually varies within several hundred mV, locally reaching 1 V and more (for example, at the Olimpiada deposit). The period of the spatial SP variations ranges from few tens to few hundreds of meters. By the spectral composition, these variations are conventionally divided, in a first approximation, into two types: low-frequency low-amplitude (usually few tens of mV) anomalies and high-frequency large-amplitude ones, relatively isomeric or linearly elongate.

These types of SP variations exist not at all fields. Only "low-frequency" SP variations are always observed (Fig. 1*a*, *c*). Both types of variations exist only at some deposits, with "high-frequency" perturbations being predominant (Fig. 1*b*) and distorting or concealing the "low-frequency" background.

Spatially large low-amplitude EF anomalies are caused mostly by groundwater circulation (usually at a velocity of about 20–40 m/day) in the subsurface zones of geologic environment (so-called filtration fields) owing to a double electric Layer in the capillaries. These SP variations are in an inverse correlation with the day surface relief (Fig. 1).

Another group of local SP anomalies (high-amplitude ones) at gold deposits is typical of rock sites enriched in electron-conducting minerals, such as graphite and metal sulfides (most often, pyrite). The nature of SP anomalies in the areas with such sites is generally known (Bigalke, 1997; Ogil'vi, 1990; Parasnis, 1965; Revil and Jardani, 2013; Ryss, 1983; Semenov, 1974). They are caused by physicochemical processes running at the boundaries between electron conductors and the enclosed watered rocks with ionic conductivity. The SP intensity is determined both by the difference in the redox potentials of waters circulating at different depths (Bigalke, 1997; Parasnis, 1965; Semenov, 1974) and by the electrode potential of electron conductors, which is not constant at the deposits but lies nearly in the same range of values (200–500 mV) and follows the near-normal distribution law (Fig. 2). The electrode potential of graphite is, on average, higher than that of sulfides.

In the study area, including the gold ore fields with a permafrost rock bed, the shape and amplitude of the "high-frequency" EF variations depend neither on the season (Fig. 3*a*) nor on the year of observation (Fig. 3*b*) significantly governing the physicochemical conditions in the active (in terms of electrical conductivity and water circulation) horizon. This indicates that the SP anomalies under study, in contrast to the "low-frequency" ones, form with the participation of pellicular (loosely bound) and capillary waters freezing at temperatures much below 0 ºC. For example, pellicular waters freeze at –78 ºC (Saukov, 1975).

The regional gold deposits can be divided into three significantly different groups according to the type of relationship between the SP morphology and gold orebodies.

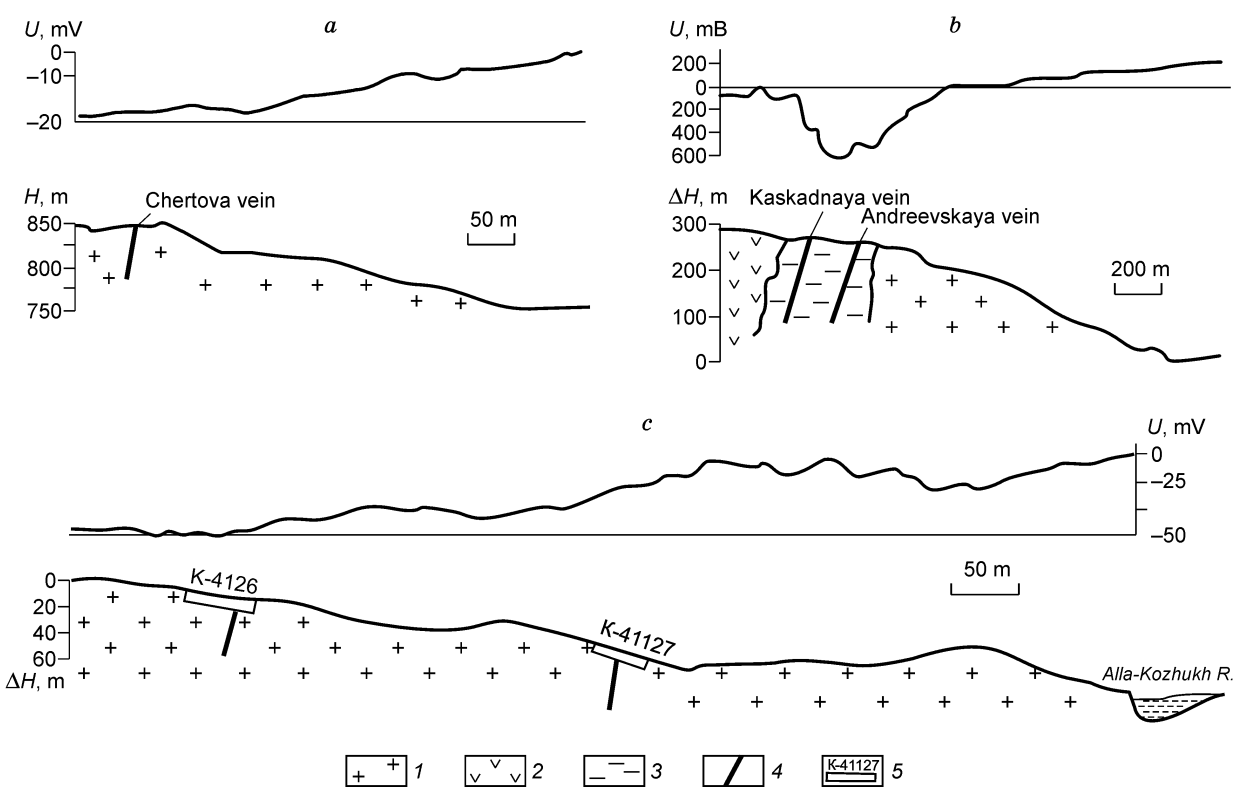

Fig. 1. Self-potential at gold deposits: *a*, Aprelkovo; *b*, Sarala; *c*, Tsentral'noe. *1*, granodiorite; *2*, basic effusive rocks; *3*, argillaceous-carbonaceous shales; *4*, ore vein; *5*, trench and its number.