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# SERPENTINES OF CHRYSOTILE – PECORAITE SERIES AS GENESIS INDICATORS OF NICKEL DEPOSITS IN THE URALS WEATHERING CRUSTS

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Data are presented on the results of X-Ray structural and thermal analyses, data from chemical and microscopic studies of serpentines of chrysotile $Mg_3Si_2O_5(OH)_4$ – pecoraite $Ni_3Si_2O_5(OH)_4$ series from the silicate nickel deposits in the Urals. Nomenclature is updated of the studied serpentines following the regulations of the International Mineralogic Association. It is demonstrated that the studied minerals are the chief ore minerals in serpentinite zones of nickel fields. Issues are reviewed of formation of serpentines of the chrysotile-pecoraite series in conjunction with hydrothermal processes. It is suggested the two-tier structure of the Ural supergene nickel fields, where supergene upper tier has "roots" in the form of hydrothermal lower tier, which significantly expands the area of the search for new fields and opens great opportunities in this ancient district of ore.

***Key words***: serpentines, chrysotile, pecoraite, weathering crusts, the Urals, nickel, X-Ray structural analysis, thermal analysis, hydrothermal process, genesis.

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**Introduction.** Ultramafic rocks, first of all serpentized harzburgites and dunites as well as serpentinites themselves serve as ore substrate for forming hypergene nickel fields. The ultramafic substrate of certain massifs is interpenetrated with dikes of basalt and granitoid composition, talc, carbonate-talc, tremolite-actinolite, chlorite and other endogenic rocks related to them genetically. Thus the widely spread opinion that hyper-genic nickel fields are formed following the ultramafic rocks, such as harzburgites, dunites and others is correct in principle but remains far from being precise.

Actually, the real ore bearing substrate for them is provided by serpentized ultramafites as well as endogenic serpentinites and their metasomatites. Meanwhile, hypergene metasomatites already formed in the weathering crusts are presented by lizardite-nepuite serpentinites, ferric oxiderocks (getites), nontronite-chloride rocks as well as lode (string) metasomatites of carbonate, manganese and other compositions. In the course of hypergene metasomatic changes the chemical composition of primary endogenic and hydrothermal-metasomatic rocks of the substrate undergoes considerable transformation, its principal components brought in or taken out, as well as Ni, Co and other chemical elements.

Among the principal rock-forming minerals of silicate Ni ores are first of all the nickel-containing silicates: serpentines, talcs, chlorites, clay minerals and hydromica, plus ferric oxides, while the secondary group consists of a wide scope of minerals, such as manganese and silicon oxides, carbonates, nickel sulfates, millerite and others. They all may gain or lose their rock-forming importance at different horizons of hypergene fields or come forth as principal ore minerals. Minerals of hypergene nickel metasomatites and ores are specific in their fine crystal or even amorphous structure and wide development of mixed-layered mineral formations.

As noted above, serpentines are outstandingly important industrial minerals of nickel ores of hypergene fields in the Urals. We studied them in mountain rocks and ores of the Buruktalskoye, Sakharinskoye, Elizavitinskoye and Akkermanovskoye fields, Elovskoye field of the Serovskaya Group, Cheremshanskoye, Rogozhinskoye, Sinarskoye fields of the Ufaleiskaya Group and other ore objects of Sverdlovsk, Chelyabinsk and Orenburg Provinces.

**Study methods.** The studies of serpentines in the Urals nickel fields were first initiated by E.F.Alexeeva and M.N.Godlevsky [1], G.S.Gritsaenko (1943, 1944), I.I.Ginzburg, I.A.Rukavishnikova (1951), I.V.Vitovskaya ([4], 1970), who performed chemical, optical, roentgenometric, thermal and other studies. Structure variability and polytypism of serpentines were studied by B.B.Zvyagin, K.S.Mishchenko, V.A.Shytov (1966, 1981) who identified 18 regular structures belonging to 12 polytypic modifications of serpentines. The latest registry of diagnostic properties of serpentines minerals was produced by I.V.Vitovskaya (Technologic mineralogy..., 1988); it was based on summing up the

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data from early studies. Serpentines of foreign hypergene nickel fields were studied in numerous works by D.Brindley et al. [13-16], D.Whittacker [18], Z.M.Maksimovich [5] and other scholars. A generalizing monograph by D.Brindley and D.Brown [14] on roentgenometry of hypergene minerals should be noted in that respect. When studying the serpentines of the Urals Province we referred to reference guides by E.I.Semyonova [9], D.Brindley and D.Brown [14], H.Schtrubel and Z.Zimmer [12].

To study and update chemical and mineral composition of rocks and ores of silicate nickel fields of the Urals we performed a wide complex of research. Chemical analyses were taken in the Central Analytic Laboratory of VSEGEI (St. Petersburg) using technique with inductionally connected plasma mass-spectrometry (ICP-MS) technique and in the laboratory of the St. Petersburg Mining University, using the atomic absorption technique, O.L.Galankina, the analyst; mineral phases were diagnosed by optical microscopy (more than 150 micro-sections and polished sections, the St. Petersburg Mining University), X-Ray diffraction and thermal analysis techniques accompanied by electron microscopy data. X-Ray diffraction analyses were taken using the X-Ray Geigerflex-D/max diffractometer (JSC Mekhanobr-Analyt, M.A.Yagovkina), XRD 3000 TT and URD-6 diffractometers (Freiberg Mining Academy, Germany, Dr. R.Kleeberg), as well as DRON-6 diffractometer (Central Analytic Laboratory, VSEGEI, V.F.Sapega). Comprehensive thermal analysis was carried out using the STA 429CD+QMS facility (Institute of Chemical Compounds Rus.Ac.Sci., V.L.Ugolkov), as well as the Thermal Laboratory of the Freiberg Mining Academy (FMA, Germany), Dr. K.Galonska, the analyst. Microscopic X-Ray spectral analyses were taken using the scanning electronic microscopes CamScan MV2300 (VSEGEI, V.F.Sapega), CamScan MX2500 (VSEGEI, A.V.Antonov), VEGA 3LMU (Research Analytic Center Institute GiproNickel, O.P.Mezentseva, PhD, Mining and Mineralogy), LEO 1413 VP c EDS Oxford (Institute of Mining Mineralogy, Siberian Branch, Rus.Ac.Sci., A.T.Titov), JEOL JSM 6400 raster electronic microscope of Applied Physics Laboratory, Freiberg Mining Academy (Germany), Dr. U.Kempe, the analyst, plus the raster electronic microscope CAMSCAN-4DV (the Radium Institute, Yu.L.Kretser). Decoding X-Ray data was conducted using the ICPDF classification (International Centre for Diffraction Data). When studying the nomenclature of serpentines reference guides were used by E.I.Semyonov [9], D.Brindley and D.Brown [14], H.Schtrubel and Z.Zimmer [12].

**Serpentines nomenclature.** The problem of serpentines nomenclature was discussed earlier by I.V.Vitovskaya [3] and one of the current authors [8, 17]. The latest registry of diagnostic properties of serpentine minerals was produced by I.V.Vitovskaya [3] it was based on summing up the data from early studies. Serpentines of foreign hypergene nickel fields were studied in numerous works by D.Brindley et al., D.Whittacker, Z.M.Maksimovich and others. One should point out the synthesizing monograph by D.Brindley and D.Brown [14] on crystal structure and roentgenometry of clay minerals. According to classification by D.Brindley and Z.Maksimovich [15] serpentines belong to the two isomorphic series: chrysotile $Mg_3Si_2O_5(OH)_4$ – pecoraite $Ni_3Si_2O_5(OH)_4$ and lizardite $Mg_6Si_4O_{10}(OH)_8$ – nepuite $Ni_3Si_2O_5(OH)_4$. Our subject matter for the current publication are the serpentines of the chrysotile $Mg_3Si_2O_5(OH)_4$ – pecoraite $Ni_3Si_2O_5(OH)_4$ series.

**Results.** ***Chrysotile*** $Mg_3Si_2O_5(OH)_4$ is widely spread in serpentinites and hypergene metasomatites developed in them in the lower horizons of the Cheremshansky and Elovskoye fields. It is found in the composition of both chrysotile serpentinites and serpentine-talc-chlorite veins running through them , but is practically never described as an individual phase in the Urals nickel fields [11]. According to our X-Ray data chrysotile is presented as two polymorphic modifications: $2Or_{C1}$ (a cylindrical structure and an orthorhombic grid) in the Cheremshanskoye field of the Ufaleyskaya Group and the Buruktalskoye field, and the $2Or_{C1}$ и $2M_{C1}$ (a cylindrical structure and a monocline grid) in the Elovskoye field of the Serovskaya Group.

As for serpentinites of the Cheremshanskoye field, chrysotile is presented there by fine fiber aggregates, while the Staro-Cheremshanskaya deposit of that field sometimes features veins of chrysotile-Asbestos up to 10 cm thick. It looks fibrous under the microscope, colorless, yellow or light yellowish-green; $Ng = 1.556$, $Np = 1.550$. The veined pecoraite-chrysotile-Quartz metasomatites of the Chusovskaya and Staro-Cheremshanskaya deposits and similar formations of the Elovskoye field have chrysotile forming separate grains and grain aggregates and is seen under the microscope as a different finely scaled isotropic substance (serpophite). Part of those are nickel chrysotiles graduating to pecoraite. Of considerable interest are metasomatic serpentine veins in the Ufaley calcite marbles, formed completely by chrysotile $2Or_{C1}$. X-Ray studies of the pecoraite-chrysotile-lizardite serpentinites of the

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Elovskoye field, taken in the Freiberg Mining Academy (Dr. Reinhard Kleeberg, the analyst) have demonstrated that beside the chrysotile $2Or_{C1}$ it features chrysotile $2M_{C1}$.

As for the X-Ray characterization of chrysotile from the Urals fields, note that the cline chrysotile in the Urals nickel field was mentioned earlier by I.V.Vitovskaya [3] in the course of studying kerolite. She took electronic-microscope photographs of kerolite pipes corresponding to Debye powder pattern of standard chrysotile according to A.S.Varlakov (Fig.1, *b*, *c*) [2]. Thus the presence of chrysotile in the composition of hypergene serpentinites of the Urals was already demonstrated by I.V.Vitovskaya, but that fact failed to provide an impulse for further studies of that mineral or to recognition of its considerable role in forming nickel fields of the Urals.

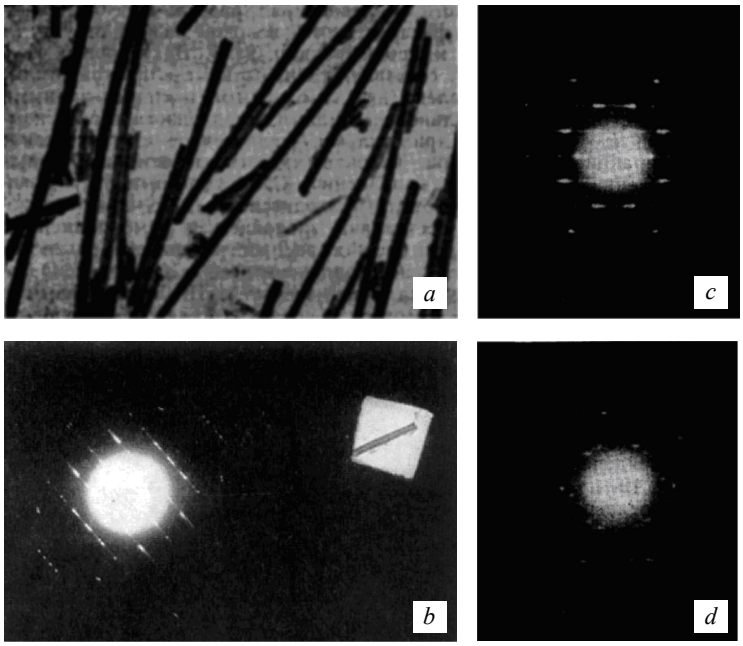



Fig.1. Electronic microscope pictures of tubular particles of cline chrysotile, magn. 50 000 (*a*) and the picture of its micro-diffraction, magn. 40 000 (*b*) after I.V.Vitovskaya [3]; chrysotile micro-diffraction picture (*c*, *d*) after A.S.Varlakov [2]

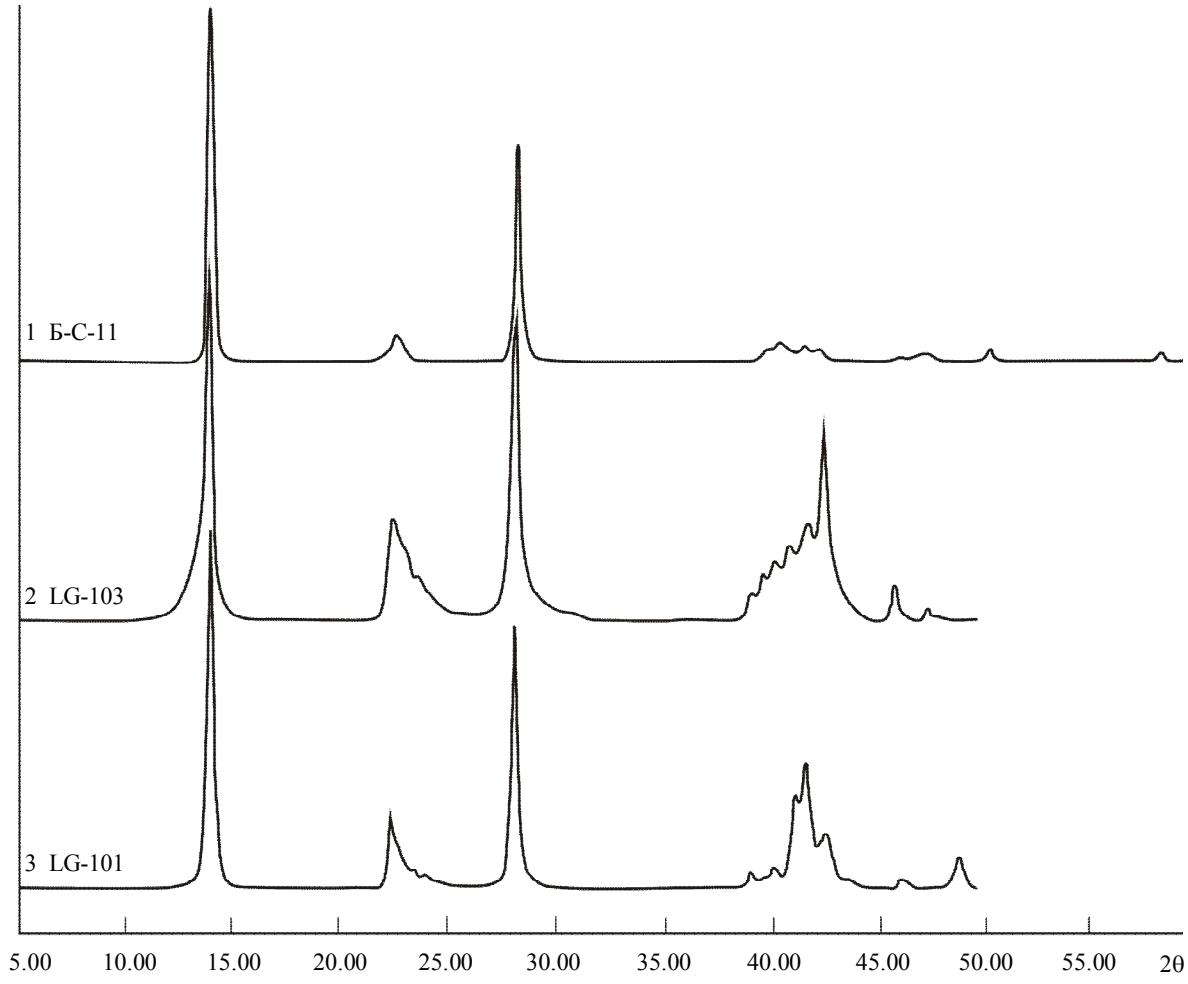



Fig.2. Chrysotile diffractograms (by the X-Ray Laboratory of Freiberg Mining Academy, Germany, Dr. Reinhard Kleeberg, the analyst)

1 – chrysotile from the serpentinite zone of Buruktalskoye field; 2 – chrysotile from the chrysotile vein in the marbles of the Cheremshanskoye field; 3 – chrysotile from the anti-horizontal harzburgite (stubachite) of the Cheremshanskoye field

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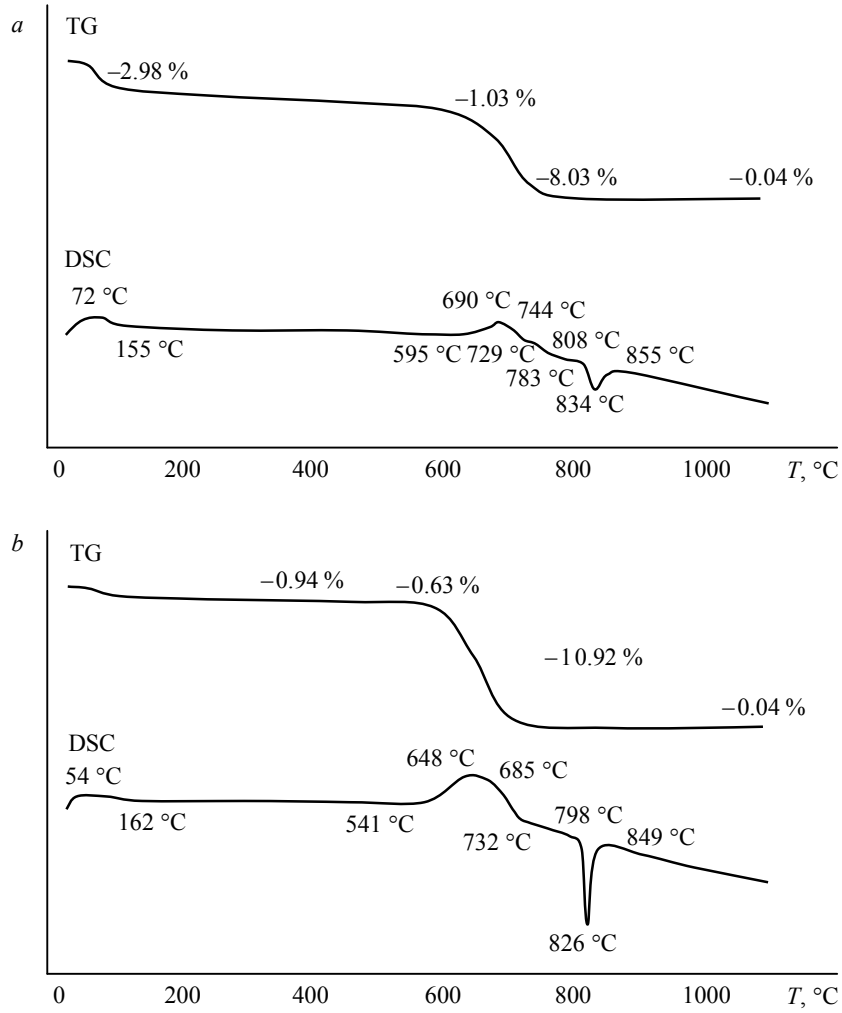



Fig.3. Results from thermal analysis of chrysotiles from the Buruktalskoye (*a*) and Elovskoye (*b*) fields (laboratory of the St. Petersburg Mining University, V.L.Ugolkov, the analyst)

Diffractograms of chrysotile from Buruktalskoye and Cheremshanskoye fields are presented in Fig.2.

Results from comprehensive thermal analysis (TG and DSC curves) for chrysotile from the Buruktalskoye and Elovskoye fields are presented in Fig.3.

It may be seen from Fig.3, *a* that the thermogravimetric curve for chrysotile from the Buruktalskoye field has three steps: 1) Within the interval from 30 to 155 ºC sample mass decreases by 2.98 % due to moisture evacuation; 2) between 155 and 595 ºC mass decreases further by 1.03 %; 3) from 595 to 783 °C mass drops by another 8.03 % due to loss of hydroxides from mineral structure; 4) from 783 to 1100 °C another decrease of mass by 0.33 % takes place, related most probably to final removal of the remnants of hydroxides. DSC curve has some endothermal peaks in the 30-155 ºC range, which corresponds to the removal of adsorbed water, plus a peak in the 595-783 °C range with a maximum at 690 °C corresponding to chemical decomposition of chrysotile. Besides, there is an exothermal peak at 834 ºC that is typical for magnesium chrysotile.

***Pecoraite*** $Ni_3Si_2O_5(OH)_4$ is a nickel analogue of chrysotile. Initially that mineral was found at the surface of the Wolf Creek weathered meteorite (Western Australia) and described by G.Faust et al. (Faust et al., 1969). Its theoretical composition includes 58.92% of NiO, so the presence of this mineral even in a small proportion turns a waste rock into an ore. Domestic publications on the Urals nickel fields practically never mention pecoraite. I.V.Vitovskaya (Technical Mineralogy ..., 1978) described the composition and properties of pecoraite following the data from foreign studies.

Pecoraite $2M_{C1}$ was initially discovered by the current authors (Talovina et al., 2003) as one of the principal ore minerals of the fields of the Urals Province in the deposits of Ufaleyskaya and Serovskaya Groups. The fields of Ufaleyskaya Group had the deep horizons of the Chusovskaya deposit of the Cherenshanskoye and North Krotovskoye fields opened up to demonstrate brecciated nickel ores with nests and veins of pecoraite, nickel chrysotile and other nickel hydrosilicates among the mesh-cellular skeleton formed by quartz and chalcedony. These are garnierite-quartz (Mikhailov, 2000) or pecoraite-chrysotile-quartz ores (Talovina et al., 2006). In the metasomatites from deep horizons of the Elovskoye field of Serovskaya Group that we discovered later pecoraite $2M_{C1}$ steps forward as the chief rock forming mineral of pecoraite and pecoraite-lizardite serpentinites and ores.

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Macroscopically pecoraite from the Cheremshanskoye field differs from chrysotile. It forms solid masses of grassy green and emerald-green color that form nests or densely branching veins of thick colloform or shell texture, several millimeters to a few centimeters in size (Fig.4). Sometimes it forms singer crusts of spherulite structure, the size of spherulites varying from a few parts of a millimeter to a few millimeters. Pecoraite is fragile, its fracture conchoidal. Its hardness is 2.5-3.5. Its luster is glassy and waxy. Internal contours of rhythmic zonality conform with the outer boundaries of serpentine excretions.



Fig.4. Pecoraite-chrysotile-quartz serpentinites of Cheremshanskoye field

Microscopic inspection demonstrates that the mineral is present in ores in the form of typical bellows-type or colloform budding shaped aggregates which feature certain zonality: the coloring of pecoraite from outer boundaries to the center becomes denser and brighter (Fig.5). Chemical composition of pecoraite is presented in Table 1.

*Table 1*

**Chemical composition of pecoraite from the Urals fields (in mass %)**

| Oxides | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 46.63 | 46.67 | 46.11 | 45.14 | 45.51 | 46.12 | 46.65 |
| $Al_2O_3$ | 0.64 | 0.75 | 0.70 | 0.34 | 1.05 | 0.45 | 0.56 |
| FeO | 1.71 | 1.87 | 1.43 | 0.99 | 1.30 | 1.19 | 1.48 |
| MnO | 0.74 | 0.31 | 0.44 | 0.10 | 0.28 | 0.20 | 0.35 |
| MgO | 25.48 | 23.87 | 23.03 | 21.44 | 23.57 | 23.78 | 23.89 |
| NiO | 24.50 | 26.53 | 27.15 | 31.82 | 27.59 | 28.26 | 26.86 |
| CoO | 0.31 | 0.00 | 0.54 | 0.00 | 0.18 | 0.00 | 0.21 |
| Pd | – | – | 0.61 | 0.16 | 0.51 | 0.00 | 0.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

*Comment*. 1-3 – Cheremshanskoye field, Ufaleyskaya Group, 4-7 – Elovskoye field, Serovskaya Group (U.Kempe, the analyst, Freiberg Mining Academy).

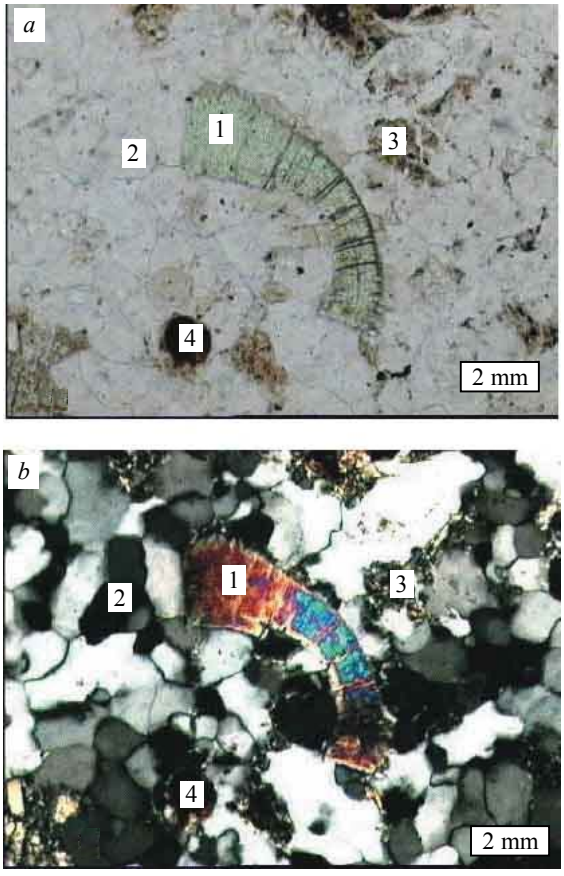



Fig.5. Bellows-shaped aggregates of pecoraite in pecoraite-chrysotile-quartz metasomatites of Cheremshanskoye field, Ufaleyskaya Group:
*a* – no analyzer, *b* – with analyzer
1 – pecoraite; 2 – quartz; 3 – serpentinite fragment; 4 – magnetite

Diffractometric curves of pecoraite from the Urals fields are presented in Fig.6. Diffractogram of pecoraite serpentinite from the Elovskoye field in which the $2M_{c1}$ pecoraite reaches 85 %, identifies that mineral well by its three "serpentine" 2θ peaks: 13.99 (CPS 7865), 28.57 (CPS 3429), 42.89 (CPS 217) and two less prominent ones. Similar picture is observed in the Ser-154.4 (3.4.14-2) specimen, its pecoraite content reaching 75 %.

Many diffractorgrams of Cheremshanskoye field feature an $2M_{C1}$ pecoraite that does not differ from the $2Or_{C1}$ chrysotile. As already noted, the two serpentines are in close interpenetration, pecoraite forming larger size individualized bellows-shaped and budding-form grains in the finely needling chrysotile. Pecoraite was also found in the lizardite serpentinites of shallower horizons in the Sakharinskoye field.

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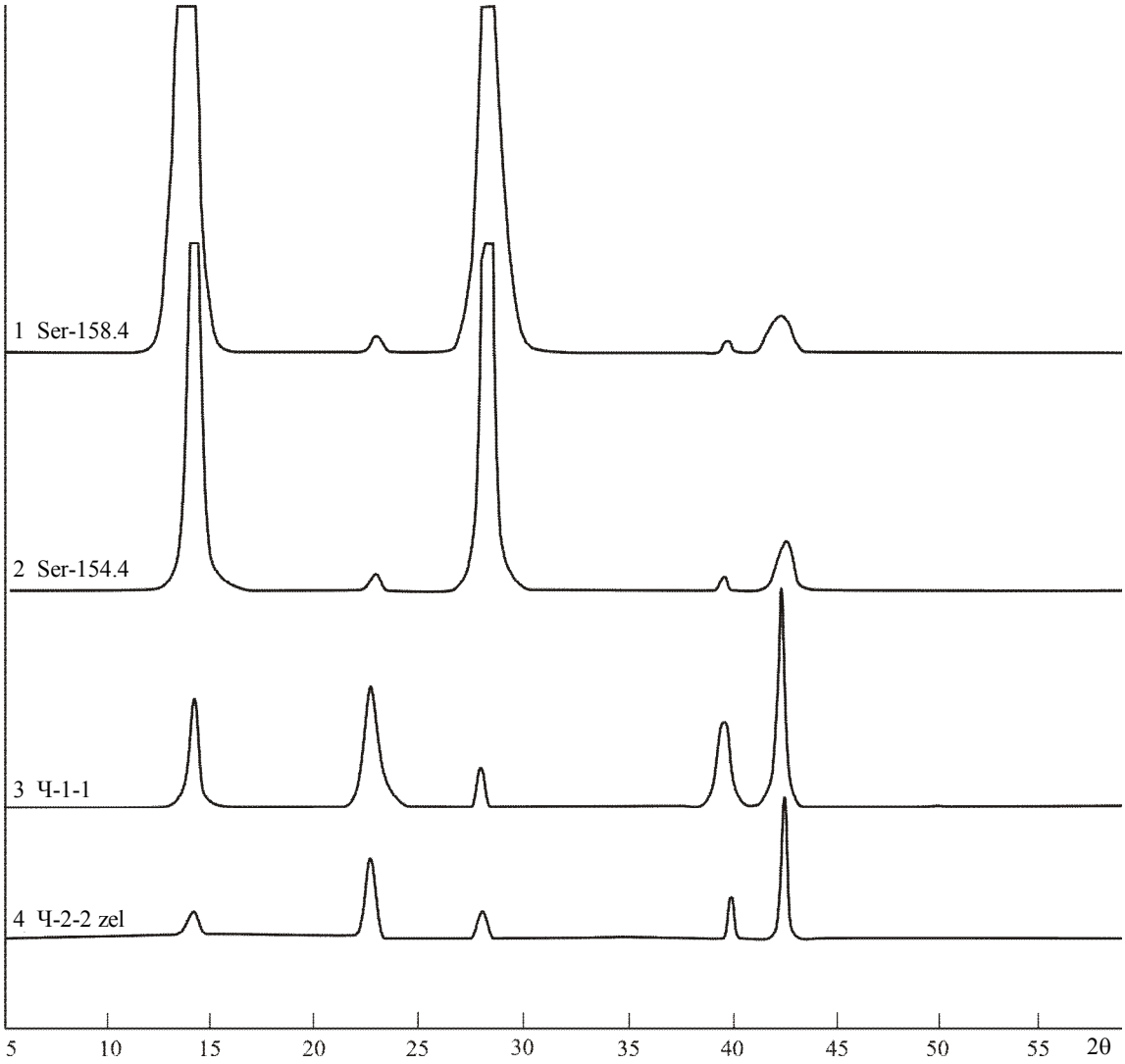



Fig.6. Diffractorgrams of pecoraite $2Mc_1$ from the Elovskoye (Ser) and Cheremshanskoye (Ч) fields

1, 2 – pecoraite from the serpentinite zone of the Elovskoye field; 3, 4 – pecoraite from pecoraite-quartz metasomatites of Cheremshanskoye field (Mekhanobr-Analyt Laboratory, M.A.Yagovkina, the analyst)

Thermograms of $2M_{C1}$ pecoraite from Cheremshanskoye and Elovskoye fields are shown in Fig.7. It may be seen from Fig.7, *d* that the TG thermogravitational curve is dropping gradually in the 0-1100 °C range following its weight loss due to evacuation of sorbed and hydroxide water. The analysis of that water points to strong variations of its content in the six analyzed specimen (from 2.16 to 11.32 %). Since the contents of hydroxide water in pecoraite is relatively stable, its increase above that level is defined by the amount of sorbed water. Three minima are identified in the TG curve, corresponding to slight loss of water at 95; 619 and 869 °C. The first such loss in the 25-166 °C range is related to evacuation of moisture, the second, most prominent one (at 619 °C) may be explained following the analogy with synthesized pecoraite [7], specifically as a loss of hydroxide constitutional water, i.e. as decomposition of pecoraite.

The DSC differential thermal curves for pecoraite of the Elovskoye field are straitly linear and are accompanied by slight endo- and exothermal peaks, their positions featuring a certain repeatability. Specifically, endothermal peaks are: 59-106 °C (moisture evacuation), 571-574 °C (quartz peak in the pecoraite-quartz metasomatites), 802-816, 869-870 °C, while the exothermal are: 100-137, 507-534, 628-693, 819-835 °C. When comparing the latter exothermal peak with the thermogram of synthesized chrysotile [7], it appears to be a weak but quite vivid relic of the typical chrysotile peak that weakens as the pecoraite component is added, and then fades away altogether.

Comparing the DSC curves for pecoraite of the Elovskoye field with those for synthesized pecoraite [7] shows that the weak exothermal peak of pecoraite from the Elovskoye field apparently points to the presence of slight amount of Mg-chrysotile. It follows from the data by E.N. Korytkova et al. [7]

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that the large exothermal peak so typical for chrysotile at 820 °C in the chrysotile-pecoraite series gradually degenerates with the growth of pecoraite (nickel) component and vanishes completely in pure pecoraite. In other words, the value of exothermal peak at 820 °C in the chrysotile-pecoraite series serves an indicator of Ni content in chrysotile or of Mg in pecoraite, which may be of practical interest for diagnosing Mg-pecoraites and Ni-chrysotiles. Similar to the quartz peak, the nature of other endo- and exothermal peaks is partly due to admixtures of other minerals (talc, clintonite, palygorskite).

**Discussion.** The conditions of forming serpentines of the chrysotile group, to which pecoraite belongs as well, were first considered in experimental studies by D. and R. Roy (Roy, Roy, 1954), E.N.Korytkova with co-authors (1972), V.A.Pokrovsky and I.P.Ivanov (1984) and other researchers. According to isotopic data by D.Wenner and H.Taylor (Wenner, Taylor, 1971), A full list of experimental and computational data on chrysotile stability range for reaction

$$4Mg_2SiO_4 + 6H_2O \leftrightarrows Mg_3Si_2O_5(OH)_4 + 2Mg(OH)_2$$
forsterite chrysotile brucite

is given in a publication by M.Gottschalk (Gottschalk, 1997). It follows from it that the position of the chrysotile-forsterite equilibrium curve changes from 320-400 °C at low pressures (< 100 MPa) to 550 °C for relatively high pressures (100-600 MPa). The nickel chrysotile-pecoraite – is no exception in that sense. The artificial synthesis of «garnierite-pecoraite», performed in weakly acidic and neutral media has demonstrated that it forms at the temperature of 250 °C and higher and pressure of 9.8 MPa (Kozyrin et al., 1968).

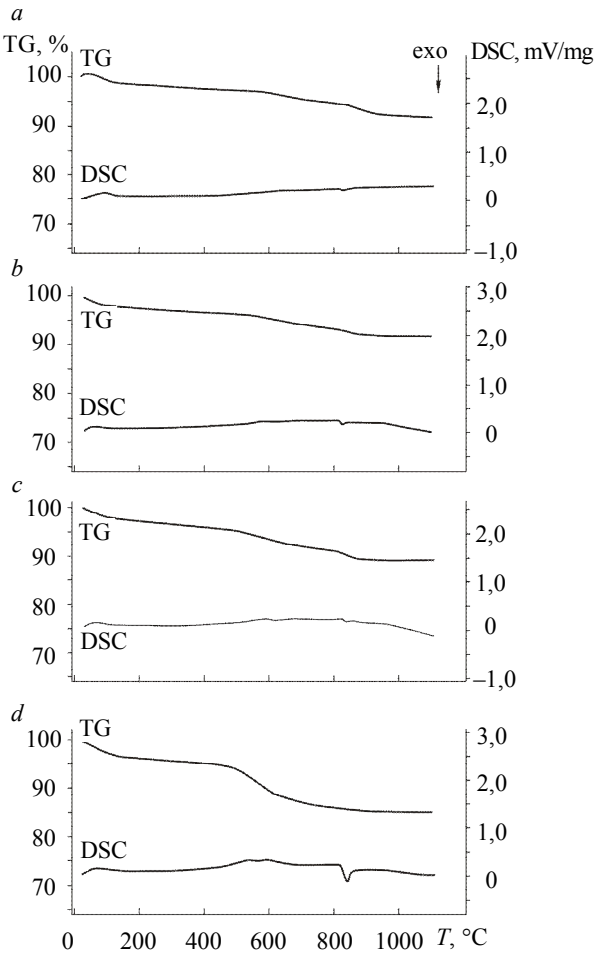



Fig.7. Results of comprehensive thermal analysis of $2M_{c1}$ pecoraite from the Cheremshanskoye (*a-c*) and Elovskoye (*d*) fields (The Mining University laboratory, V.L.Ugolkov, the analyst)

Certaim information on the temperature of serpentines formation may be retrieved from experimental data by E.N.Korytkova et al. [7], who synthesized nanotubular hydrosilicates in the $Mg_3Si_2O_5(OH)_4$ – $Ni_3Si_2O_5(OH)_4$ system. The initial products in that experiment were presented by $NiSiO_3$, $Ni(OH)_2$ and MgO. Experiments were run in hydrothermal conditions at temperatures of 50-500 °C and pressures of 30-100 MPa in base medium. The obtained phases included serpentines of lamellar and tubular shapes (Table 2).

Serpentines of the lizardite-nepuite series are of lamellar shape, chrysotile-pecoraite series are of tubular shape. It follows from Table 2 that lamellar lizardite-nepuites are formed at temperatures up to 400 °C, while the temperature range of 250-400 °C have serpentines of both lamellar and tubular shape formed, and above that temperature the synthesis of tubular crystals of chrysotile-pecoraite starts.

Thus experimental and computational data point to apparently not exogenic, hydrothermal character of forming of these minerals in the nickel fields of the Urals Province.

So what was the cause for the appearance of the Urals hydrothermal chrysotile and pecoraite? For pecoraite-chrysotile-quartz metasomatites and ores of the Cheremshanskoye field that cause could be the contact-metasomatic impact of ther-

*Table 2*

**Lamellar and tubular serpentine formation temperature in the system of $Mg_3Si_2O_5(OH)_4$ – $Ni_3Si_2O_5(OH)_4$, °C**

| Initial products | Formation | | |
|---|---|---|---|
| | lamellar | lamellar and tubular | tubular |
| $NiSiO_3$ + MgO | 200-400 | 250-400 | 400-500 |
| $NiSiO_3$ + $Ni(OH)_2$ | 300-400 | | |

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mal field and fluids Contact-metasomatic impact of the thermal field and fluids of the Chusovsky diorite massif (Varlakov, 1992), breaking through the ultrabasites of the Ufaleisky massif during the Middle Carboniferous age (320-315 Ma). Outcrops of chlorite-garnet skarns that we observed at the bottom of the pit of Cheremshansky deposit served as a direct evidence of this process. High content of granitophile-lithophile and chalcophile elements, especially gold, barium and yttrium, foreign for ultramaphites imported from the diorite magma of the Chusovsky massif, in the Cheremshanskoye deposit metasomatites and ores is another proof of such impact [8].

Meanwhile the main cause of hydrothermal genesis of the Urals serpentines of chrysotile-pecoraite series lies with the relatively ancient lower Ordovician ($O_1$?) age of the Urals ultramaphites. Upon their penetration these ultramaphites were subjected to a large scale injection of granitoid and other magmas, which resulted in forming such major and unique contact-metasomatic objects in the Urals as the Bazhenovskoye deposit of chrysotile-asbestos, the Malyshevskoye deposit of beryllia-phlogopite ores and a number of other deposits of similar genesis. Pecoraite-chrysotile-quartz mineralization of Cheremshanskoye and Serovskoye fields are the consequence of the same process of contact metasomatosis. The process was accompanied by redistribution nickel, cobalt, elements of the platinum group, gold and silver in the ultramaphite substrate. Due to all that the exogenic ore process did not superimpose on the «fresh» dunite-harzburgite substrate with Ni content of 0,2-0,4 %, in the Urals Province, as descriptions of the hypergenic nickel deposits commonly describe [6], but instead it went on a prepared ultramaphite substrate formed by serpentinized ultramaphite rocks and serpentinites, chlorites, talcites, phlogopitites and vermiculites, i.e. a rather differentiated protolyte of inhomogeneous content of Ni, Co, platinoids, Au, Ag and other elements [10]. That circumstance is well documented now in the course of developing the Urals deposits as the initial substrate inhomogeneity produces additional difficulties in the process of exploiting ore bodies.

Interestingly, the hypothesis of hydrothermal formation of garnierite veins was first suggested by pioneer explorers of the deposits of New Caledonia. By way of argument they pointed to the wide proliferation areal of garnierite veins compared to that of weathered rocks. The veined garnierite deposits of New Caledonia (Mondu, Koniambu, Nepui, Poro, Tio) had yielded 90 thou. tons of ore with nickel content of 6.5 % in the beginning of last century.

Therefore the important practical conclusion following from the genesis of the Urals chrysotile-pecoraites is the need for additional survey of the deposits to larger depths, since hydrothermal mineralization is not limited by subsurface zone but assumingly penetrates depth-ways and side-ways with its extended ore deposits. It is especially well seen with the example of the Cheremshansky deposit where exploratory wells of 400 m deep failed to break out of the ore zone. One may assume for the Urals Province that its hypergenic nickel deposits are characterized by a double-decker structure in which the upper layer features deep reaching “roots” in the form of the lower hydrothermal tier. One should rather not exclude that the Sakharinskoye, Buruktalskoye and other deposits feature deep reaching hydrothermal extensions that call for deploying deeper reaching wells than those drilled on the hypothesis of hypergenic genesis. With this approach one may consider the deposits mentioned as under-surveyed with all the implications following.

Generally, establishing the hydrothermal genesis of the Urals serpentines of the chrysotile-pecoraite series supports the “hydrothermal-vadose” hypothesis by V.N.Razumova (1977) and the “thermal-hypogenic” hypothesis by B.M.Mikhailov (2002) from the position of substantive analysis of nickel ores.

**Conclusion.** The studies conducted have resulted in streamlining the serpentines’ terminology for the Urals Nickel Province in accordance with regulations by the International Mineralogy Association; presence is demonstrated of pecoraite a $2M_{C1}$ and Mg-pecoraite, as well as chrysotile $2Or_{C1}$ in metasomatites and ores of the Cheremshanskoye and Elovskoye deposits of the Urals Province, these being the extremely important industrial minerals of silicate nickel deposits in the Urals. They form in the relatively high temperature environment and serve as indicators of hydrothermal origin of a part of silicate nickel ores of the Urals Province. One may assume for the Urals Province that its hypergenic nickel deposits are characterized by a double-decker structure in which the upper layer features deep reaching “roots” in the form of the lower hydrothermal tier.

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The prospective hydrothermal hypothesis for nickel deposits of the Urals is exceptionally actual right now, as hypergenic ores are practically exhausted in the Urals to the exception of the ores of Serovskoye and Buruktalskoye fields, so that the mineral resource base of nickel industry here encounters serious difficulties. Hydrothermal hypothesis expands the range of searching for new deposits considerably and opens new major possibilities for that ancient ore areal.

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