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MINISTRY OF MINING AND HEAVY INDUSTRY

METHODICAL RECOMMENDATION APPLIED FOR CLASSIFICATION OF MINERAL RESOURCES AND CERTAIN TYPE DEPOSITS' RESERVES OF MONGOLIA

(MANGANESE)

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The METHODICAL RECOMMENDATION applied for classification of mineral resources and certain type deposits' reserves of Mongolia

MANGANESE

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This recommendation is designed for employees of enterprises and organizations operating in the sector of subsoil use, regardless of their departmental affiliation (or subordination) and ownership.

The application of the "METHODICAL RECOMMENDATION…" will useful to be provided geological information, the completeness and quality of which are sufficient to make decisions on further exploration or on the involvement of reserves of explored deposits in industrial development, as well as the design of new or reconstruction of existing enterprises for the extraction and processing of minerals.

CONTENT

Preface

The recommendation was produced in accordance to a number of provisions of relevant law, decrees and regulations as follows: “Regulations on Mineral prospecting and exploration activities” approved by order #A/20, 2018 by the Mining & Heavy Industry Minister, as well as a provision approved by a Mining Minister order #203, 2015, which specifies that “The present recommendation for classification of mineral resources and deposit reserves can be applicable to a mineral resource in compliance with any recommendations for a certain type of mineral on the basis of its characteristics”.

The recommendations provides the practical assistance for entities who own exploration and mining licenses, geologists, prospectors, miners and aluminium ore mining organizations to compile a final report on reserve estimation, to have the estimated reserves registered to the state mineral resource register and update reserve data.

One. Basic concepts

1.1. Manganese is a silvery-white brittle metal having a density of 7.2-7.46 g/cm^3, a melting point of 1244 °C, a boiling point of 2061°C. About 90% world production of manganese ore is used in metallurgy of iron and steel. Adding 0.3-14% manganese to various alloys increases the alloy's ability to withstand shocks and vibrations, but also makes it more resistant to abrasion. Therefore, manganese-containing alloys are used to make electrical meters and various machine parts. It is also used in the manufacture of dry batteries, in the chemical industry, in the manufacture of ceramic glass, in the manufacture of clarifiers and electrodes.

1.2. The average (clark) content of manganese in the earth's crust is about 0.1%, in various rocks it ranges from 0.06 to 0.2%. Manganese occurs in nature mainly in the form of oxides, hydroxides, carbonates and silicates. More than 150 minerals containing manganese are known, but only a small part of them is of industrial importance (Table 1).

Table 1.

Major minerals containing manganese

Mineral	**Chemical formula**	**Mn content, %**
Pyrolusite	MnO_2	60–63,2
Gausmanite	Mn_3O_4	72,0
Brownite	$3Mn_2O_3MnSiO_3$	60–69,5
Psilomelane	$(Ba, Mn^{2+})_3 Mn^{4+}_8 O_{16}(OH)_6 \cdot\bullet nH_2O$	45–60
Jacobsite	$MnFe_2O_4$	50–55
Manganite	$MnOOH$	62,5
Vernadite	$MnO_2 \cdot nH_2O$	44–52
Todorokite	$(K, Ca, Mn^{2+}) (Mn^{4+}, Mn^{2+}, Mg)_6O_{12} \bullet 3H_2O$	47–54
Rhodochrosite	$MnCO_3$	47,8
Alabandite	MnS	60,4
Galaxite	$MnAl_2O_4$	50,5–52,3
Rhodonite	$CaMnSi_3O_{18}$	32–43
Rancieite	$(Ca, Mn^{2+}) Mn^{4+}_4 O_9 \cdot\bullet 3H_2O$	43–50
Bustamite	$(Ca, Mn)_3(Si_3O_9)$ Fe, Mg, Zn	12–20

1.3. Manganese ore deposits are classified by reserves into 3 types: large 30 million ton, medium 10-30 million ton, small up to 10 million ton. However, there are different classifications of manganese deposits depending on the origin and accumulation of manganese deposits across countries and continents. In Central Asia, manganese reserves range from 0.3-3 million tons in small deposits, 3-30 million tons in medium-sized deposits, and more than 30 million tons in large deposits. 35%) and classified as poor (10-20%) deposits (Regional Metallogeny of Central Asia, 2012).

1.4. Main industrial types of manganese ore deposits are represented by: marine sedimentary and volcanogenic (hydrothermal)-sedimentary, metamorphosed and hypergenic, as well as deposits of ferromanganese formations (nodules, crusts) of the seabed and oceans (Table 2).

Table 2.

Industrial type of manganese deposit and major type of ore

Industrial type	Geological type of ore	Mineral type of ore	Average content Mn, %	Industrial (Technological type) of ore	Examle of a deposit
1	2	3	4	5	6
Marine sedimentary	Layer of sedimentary rock	Rhodochrosite	16–48	Metallurgical manganese carbonate (sorting, gravitational-magnetic)	Novoberezov
		Pyrolusite - Psilomelane	26–50	Chemical manganese pyroxide (sorting, gravity-magnetic)	Chiatura (Georgia), Toli bulag, Khurmen, Unagad (Mongolia)
Volcanogenic (hydrothermal)-sedimentary	Layer-lens shaped volcanogen sedimentary rock	Rhodochrosite (Calcite-manganese)	16–32	Metallurgical manganese carbonate (sorting, gravitational-magnetic)	Usinsk, Porozhinsk
		Hematite-Gausmanite - Brownite	16–35	Metallurgical manganese oxide (gravitational-magnetic)	Durnovsk
		Brownite - Gausmanite - Magnetite with rhodochrosite	20–35	Metallurgical manganese oxide (gravitational-magnetic)	South-Khingyan
Metamorphosed	Layer-lens like shaped metamorphosed rock	Gausmanite - Pyrolusite - Rhodochrosite	12–28	Metallurgical manganese oxide-carbonate (sorting, gravitational-magnetic)	Parnok, South Africa, India and Brazil, Khukh teeg (Mongolia)
Hypergenic	Lineal and areal laterite weathering of magmatic, sedimentary and metamorphic rocks	Pyrolusite - cryptomylan with hydroghyotite	15–45	Metallurgical manganese oxide-carbonate (sorting, gravitational-magnetic)	Nicoliave
		Гётит-вернадит-Psilomelane	16–28	Metallurgical manganese oxide-carbonate (sorting, gravitational-magnetic)	Shungulesh (occurrence)
		Pyrolusite - Psilomelane	26–37	Metallurgical manganese oxide-carbonate (sorting, gravitational-magnetic)	Kipchak (occurrence)
		Psilomelane - вернадитовый	25–30	Metallurgical manganese oxide-carbonate (sorting, gravitational-magnetic)	Usinsk
		Vernadite-Psilomelane - Pyrolusite	15–28	Металлургический марганцевый оксидный (промывочный, сортировочный, гравитационно-магнитный)	Porjinsk
		Pyrolusite-Psilomelane	10–19	Metallurgical manganese oxide-carbonate (sorting, gravitational-magnetic)	Gromov

1	2	3	4	5	6
Ferromanganese formations (nodules, crusts) of the seabed and oceans	Areal	Co-Fe-Mn nodule	20–30 (Fe, Co, Ni, Cu)	Металлургический, химический кобальт-марганцевый оксидный (гидрометаллургический) Metallurgical, chemical Co-Mn oxide (hydrometallurgical)	In the abyssal part of the seabed (TMM) or deep pool between the mountains and the elevation (KMK)
		Fe-Mn nodule	5–30 (Fe)	Metallurgical, Ferromanganese oxide (hydrometallurgical)	Shelf Finski Bay

Marine sedimentary deposits are of the greatest industrial importance, they contain more than 80% of the world's reserves of manganese ores. Typical representatives of this type of deposits are Nikopoly, Great Tokmak (Ukraine), Chiature (Georgia), Varna (Bulgaria) contained in sandy-clay deposits of the Lower Oligocene and forming the largest Black Sea province. Also included are Australia's Grud Island and Gabon's Monda.

The ore body formed a layered, lens type and consist of several (up to 25) bodies separated by rock layers. The thickness of ore layers ranges from 0.1 to 4 m, and ore deposits - up to 11 m (Chiature). The total lateral length of the ore areas reaches 200-250 km (Southern Ukraine, Trans-Urals). In the composition of ores, oxide, oxide-carbonate and carbonate varieties are widely developed, successively replacing each other in the direction of wedging. The ore has a layered, solid, mosaic and oolitic texture. Oolite ore is a sandy-clayey aggregate that is easily enriched by washing with water.

The Tol Bulag, Khurmen and Unagad deposits discovered in Mongolia are all of sedimentary type.

Volcanogenic (hydrothermal) - sedimentary deposits are localized as part of volcanogenic-sedimentary formations that correspond to various stages of geosynclinal development of folded zones and differ from each other in the material composition of ore-bearing rocks, the ratio of volcanic and sedimentary components of paragenesis. On the territory of the CIS, the most important industrial importance is the volcanic formation. Ore deposits have the form of lenses, formation bodies of various thickness and extent, which lie in accordance with the host rocks. The ores of the deposits have been modified to varying degrees under the influence of regional metamorphism, and therefore often have a complex mineral composition. The main minerals of the ores are manganese oxides (gausmanite and brownite). Manganese silicates (rhodonite, bustamite, spessartin) are present in a number of deposits. Manganese ores are often associated with ores of other metals: iron - Magnitogor group of deposits (Russia), iron and polymetallic – Atasuy group of deposits (Kazakhstan), deposits such as Kalahari (South Africa) and Balaghat (India).

Manganese occurrences of volcanogenic-sedimentary manganese in Mongolia occur in the Khangai-Khentii accretion wedge terrain in connection with swastika and hasquartzite clamps, but the manganese accumulation is similarly small due to the small size of the clamps.

Metamorphogenic deposits are associated with manganese-containing silicate rocks - gondites and itabirites, comprising interlayers and lenses of manganese ores characterized by a wide variety of manganese-containing minerals, among which oxides (braunite, gausmanite), carbonates (rhodochrosite, manganocalcite) and silicates (rhodonite, bustamite) predominate. Ore strata have a significant total capacity and length (tens of kilometers). The largest manganese ore objects of this type are known in South Africa, India and Brazil. In Russia, the Uthum manifestation in the Sayans is associated with the gondite formation.

The Khukh Teeg deposit in Mongolia can be included in this category. The deposit is composed of calcareous sediments of the Oortsog formation, located in the brackish zone with metasomatous changes at the boundary of Permian granite. The main minerals are pyrolusite and manganese. Pre-Cambrian gonite deposits are included in this category. Gondite is a dense metamorphic rock containing spessartine, quartz, gausmanite, brownite, rhodonite, amphibole, and biotite.

Weathering deposits (hypergenic) are formed in the hypergenesis zone of primary manganese ores and manganese-bearing rocks containing manganese minerals of lower valencies - carbonates, silicates, oxides (braunite, gausmanite). Significant deposits of this type are known in West Africa, South America, and India. The deposits are a series of layers and lenses of pyrolusite-psilomelane high-quality ores. There are no hypergenic deposits on the territory of Russia, and the ores of the hypergenesis zone are manifested in all manganese deposits and are mainly associated with Mesozoic-Cenozoic weathering crusts (Usinskoye, Parnokskoye, Durnovskoye, Nikolaevskoye, Mazulskoye, etc.) and, sometimes, determine the industrial value of the deposit (Porozhinskoye).

Accumulations of ferromanganese formations at the bottom of the seas and oceans belong to promising complex deposits formed during sedimentation and diagenesis of modern sediments. According to the conditions of education, deep-water and shallow-water are distinguished among them.

Ferromanganese nodules (LMC) and cobalt-manganese crusts* (CMC) are found in all oceans.

LCMS are concentrated on the abyssal valleys of the oceans mainly at depths of 4800-5500 m. The vast majority of ore fields are located in the Pacific Ocean, especially in the Clarion-Clipperton zone. (1500×2000 km). The density of nodules (their mass per 1 m2 of the bottom) varies widely, rarely exceeding 30 kg/m2.

Nodule deposits are complex deposits of Mn, Ni, Co and Cu. The diameter of the nodules is 0.1-n * 10 cm, mainly 3-7 cm. Nodules contain (%): Mn 25-30; Fe 6-12; Ni 1-2; Co 0.2-1.5; Cu 1-1.5; P 0.5-1; Mo, REE, V, platinoids, Au and other components were found as impurities in them.

Of potential interest are cobalt-manganese nodule-crustal formations of the World Ocean, known on seamounts and oceanic uplifts at depths from 300 to 4000 m, where they often form coatings with a thickness of several millimeters to 10 cm on bedrock or compacted sediments. The crusts are composed of Fe hydroxides and contain Mn, Co, Ni, Cu and R.

Ferromanganese nodules* (LMC) at the bottom of the Gulf of Finland of the Baltic Sea are a new type of mineral raw materials, the use of which is due to the acute shortage of manganese-containing ores in Russia. Ores have been studied purposefully only since 1999.

LCMS lie directly on the surface of the seabed and form deposits of relatively small (3-15 km) sizes at a depth of 10-90 m. In the concretions, manganese hydroxides and oxides make up 65-70% of the total mass of the ore substance, iron hydroxides 30-35%. The Mn content in the LMC ranges from 5 to 30%, Fe 5-30%, P 1-5%, organic matter 7.5-24% with an average of 11.5%.

The deposits of offshore LCMS of the Gulf of Finland differ significantly from the known deposits of deep-ocean LCMS in terms of the morphology of the layers, the conditions of formation and occurrence, the mineral and chemical composition of nodules, the technology of their extraction and processing. Offshore LCMS, unlike deep-sea ones, can be considered exclusively as manganese ore.

1.5. No large or medium-sized manganese deposits have been discovered in Mongolia, and 6 small deposits and about 30 occurrences have been identified. These are mainly sedimentary and metamorphic sedimentary deposits. A brief description of some of the explored manganese deposits in Mongolia is shown in Table 5.

1.6. According to the mineral composition, manganese ores are divided into oxide, carbonate and mixed. Oxide ores are of the greatest industrial importance, in which the main ore minerals are manganese oxides and hydroxides (pyrolusite, psilomelan, jacobsite, manganite, braunite, gausmanite, etc.).

Oxide ores include oxide ores (primary pyrolusite, psilomelan, manganite, braunite, jacobsite, etc.) and oxidized – mainly carbonate ores developing in the weathering crust (pyrolusite, psilomelan, vernadite, todorokite, cryptomelan).

Oxide ores are intensively used by industry, as they are characterized by a high content of manganese, are easily enriched by simple screening and serve as high-quality raw materials suitable for the chemical industry and the production of standard grades of ferromanganese.

Abroad, oxide (peroxide – pyrolusite, nsutite) ores (Mn 50 ± 8%) of low phosphorous (P 0.04–0.08%) are of the greatest industrial importance, as a rule used without enrichment.

Among the ores of this type, peroxide ores are distinguished, differing mainly in pyrolusite mineral composition. As a criterion for classifying manganese ores as peroxide, the peroxide coefficient is used – the ratio of the content of manganese dioxide to the content of total manganese ($K = MnO_2 /Mn$): ores are peroxide if the peroxide coefficient is ≥ 1.3 with an MnO_2 content of ≥ 41.8%. The peroxide ores of Georgia (Chiatura deposit) are poor (26% Mn) - the only ones in the CIS from which high-quality pyrolusite concentrates are obtained by enrichment.

In Russia, the main industrial importance is oxidized ores of weathering crust – manganese and ferromanganese, from low-phosphorous (P < 0.1%) to high-phosphorous (P > 0.3%) – Usinskoye, Porozhinskoye, Nikolaevskoye, Parnokskoye, Durnovskoye and other deposits.

The oxide ores of the LC and CMC of the bottom of the seas and oceans stand somewhat apart. The ores are naturally alloyed and can be widely used in ferrous metallurgy: at a Mn content of 10-35% – for the production of mirror cast iron, at 5-10% – for the production of manganese cast iron. This is a direct alloying process, which is slowly being implemented in Russian factories. It is believed that when the Mn content in iron ore is more than 15%, energy costs exceed the necessary economic effect (ores are difficult to melt), but the direct alloying process leads to significant savings in expensive manganese alloys.

Carbonate ores are composed mainly of manganese carbonates: rhodochrosite, manganocalcite, and manganese calcite. Ores with relatively low manganese contents (not exceeding 20-25%) and relatively high phosphorus content are characterized by difficult enrichment and high cost of concentrates, however, due to the reduction of oxide ore reserves and the search for advanced processing technologies, their share in manganese production will steadily increase.

As a result of the use of new enrichment schemes and borehole underground and heap (vat) leaching, carbonate ores with rhodochrosite, manganocalcite, etc. come out on top in terms of industrial significance. Ores from poor (15-25% Mn) to rich (37-48% Mn). In Russia, reserves and forecast resources of poor ores and ores of average quality are estimated in tens-hundreds of millions to a billion tons (Novaya Zemlya, Arkhangelsk, Sverdlovsk, Kemerovo region, Republic of Khakassia, Irkutsk Region, Khabarovsk Territory, Magadan Region, etc.).

Manganese limestones (5-10% Mn, 46-52% CaO) are of great potential importance for ferrous metallurgy, which can be used as a flux and deoxidizer: 1 million tons of alloyed manganese flux limestones (Ulutelyakskoye deposit in the Republic of Bashkiria, Usinskoye deposit in the Kemerovo region, etc.) will save about 20 thousand tons of manganese alloys.

Mixed ores are a transitional type between oxide and carbonate. Their chemical composition depends on the quantitative ratio of oxides (manganite, pyrolusite, psilomelane) and manganese carbonates (manganocalcite, rhodochrosite), according to which ferromanganese, carbonate-silicate, oxide-silicate, oxide-silicate-carbonate, etc. are distinguished. They are most clearly manifested at the Bolshetokmakskoye deposit in Ukraine, where selective products are isolated by enrichment – oxide and carbonate mineral types, which are further subjected to deep enrichment to obtain commercial products.

Carbonate-silicate, oxide-silicate, oxide-silicate-carbonate mixed ores may be of industrial interest provided a small amount of manganese silicates and a reduced phosphorus content. The industrial technology for the enrichment of carbonate-silicate ores to produce marketable liquid products has been developed only in Australia: for the sale of Ca-Si-Mn, the industrial product (32-37% Mn) is refined by mixing with rhodochrosite or pyrolusite-psilomelane rich concentrates.

Fe-Mn ore: In addition to manganese, iron may be present in the ores, the amount of which is sometimes significant. According to the ratio of these elements, the following are distinguished:

a) ferromanganese ores, in which both metals are in significant quantities, often with a predominance of iron ($Mn/Fe \leq 1$);

b) manganese iron ores (with a manganese content of 5-10%). Due to the close coalescence of these minerals, ores are difficult to enrich.

Brownite-gausmanite ores are formed with weak metamorphism of sedimentary deposits. They are of considerable industrial interest, but do not form large deposits and are mined in small quantities. Iron oxides and manganese carbonates are present as impurities in the ores.

Ores are characterized by interspersed, massive, layered textures, during enrichment they are re-crushed, concentrates require briquetting.

Tungsten, nickel, cobalt, gold, silver, zinc, lead, thallium, barium, boron, and phosphorus are often present in manganese ores. The latter is a harmful impurity, strict requirements are imposed on its content in the concentrate. Gold is fine and fine, is in a free state and can be extracted by mechanical means.

Phosphorus is associated with manganese, iron and apatite minerals: in the latter case, an industrial product with a content of up to 30% P_2O_5 is released during enrichment, phosphorus is extracted from manganese and iron minerals by leaching.

Tungsten is represented by its own minerals (wolframite, hubnerite, scheelite) and is allocated to its own industrial product. Nickel, cobalt and other non-ferrous metals can be isolated by leaching.

In the USA (Franklin zinc deposit, New Jersey) manganese and iron are isolated from franklinite ores (franklinite – (Fe, Mn, Zn)O $(Fe, Mn)_2O_3$). Zinc is released from the ore by oscillation, the precipitate contains up to 15% Mp and about 40% Fe used for the production of mirror cast iron.

1.7 In 2020, the world's total manganese reserves are estimated at 1.3 billion meters. South Africa has the largest manganese reserves in the world (https://www.statista.com/). Manganese ore is mainly produced in Australia, South Africa, India, China, Kazakhstan, Gabon, Brazil, Ukraine and Georgia. Manganese prices are expected to be $ 4.5 per ton between 2020 and 2021.

Two. Grouping deposits by geological complexity for exploration purposes

2.1. Following the Instruction "Classification and guide of Mineral Reserves Mineral Resources of Deposits" that approved by the order No. 203 of the Minister of Mining of Mongolia, dated on September 11th, 2015, and depending on size of ore body, shape and thickness, changes of internal structure and quality of mineral resources of manganese deposits belong to I, II, and III groups.

2.2 The I group includes sedimentary deposits of a simple geological structure with ore bodies represented by large layer-like horizontal or slightly inclined deposits of a simple structure, with sustained capacity, uniform distribution of manganese and a regular change of various types of ores (Nikopol and Bolshetokmak deposits in Ukraine). Currently, no Group I deposits have been identified in Mongolia.

The II group includes sedimentary deposits of complex geological structure with ore bodies, represented by large gently falling stratiform deposits of complex structure with an unstressed capacity, uneven distribution of manganese, a complex and irregular combination of various types of ores. These are the Unagad deposit (Mongolia), the Chiatura deposit (Georgia), the North Ural group of deposits (Russia), as well as volcanogenic (hydrothermal)-sedimentary and metamorphogenic deposits with large and medium-sized stratiform deposits of complex structure, uneventful capacity, with uneven distribution of manganese and irregular change of various types of ores (Western Kara-Jal, deposits of the Gulf of Finland LMC).

Group III includes small and medium-sized, lens-type, very complex geological settings ore bodies with very unevenly distributed mineralized weathering deposits, small-scale, unstable thick strata with complex formations, and ore-like ore bodies with very uneven distribution. The spatial location of the species includes unstable, sedimentary and metamorphic deposits, and some of them. Examples of Group III deposits include the Tol Bulag in Mongolia, the Khukh Teeg manganese deposit, and the Southern Hyangan manganese deposit in Russia

2.3 It is necessary to explore compexity of the geologic settings of the ore body which hosts more than 70% of total reserves and decide which group the target deposit should be referred to.

2.4The exploration system and grids density selection depend on a number of natural factors such as existing condition of target ore body, its structure, geologic settings, stability, volume and size and variability of economic components. Therefore, it is recommended to use following parameters to categorize the deposits on the regular basis of complexity of the geologic settings.

Ore mineralization coefficient, applied for separation of the unit block certain deposit rserve with interrupted mineralization, is calculated as follows:

$K_x = \frac{\sum l_i}{L}$ where

l_i – linear dimensions of ore intervals revealed by drilling and excavation,

L – total linear dimensions of mineralized intervals resulted from drilling and excavation

1. The complexity coeeficient of the deposit is computed as follows:

$q = \frac{N_x}{N_x + N_{xг}}$ where

N_x – number of excavation and drillholes revealing mineralization,

$N_{xг}$ – x number of excavation and drillholes revealing no mineralization.

2. Variability of ore body thickness is calculated as follows:

$V_m = \frac{\sigma_m}{\overline{m}}$: where,

V_m – x varioability coefficient of ore body thickness,

σ_m – dispersion of ore body thickness , $\overline{m}$ – average thickness of ore body

3. Grade variability of mineral components is calculated as follows:

$V_a = \frac{\sigma_a}{\overline{a}}$: where,

V_a – variability coefficient of grades of mineral components,

σ_a – dispersion of mineral components,

$\bar{a}$ – average thickness of ore bodies.

The table provides the reference of classified groups in relation to some statistical assessments of geologic settings complexity and indicates which group a deposit should belong to.

Statistic assessment and Complexity group for geological settings of deposit

Table 3.

Groups	Complexity parameters of deposits due to geologic settings			
	K_x	q	V_m	V_a
I group deposit	0.9-1.0	0.8-0.9	<40	<40
II group deposit	0.7-0.9	0.6-0.8	40-100	40-100
III group deposit	0.4-0.7	0.4-0.06	100-150	100-150

Three. Geological setting of deposit and studies of ore mineral component

3.1. For an exploring deposit, it is recommended to choose a topographic base map, of which scale corresponds to its size and features of the geological structure. Topographic maps and plans for deposits of apatite and phosphorite ores are usually compiled at scale 1:2000 to 1:5000, and for large deposits - 1:10,000. In deposits that are small in area or with a highly delineated landscape, the scale of the topographic base map should not be smaller than 1:500 to 1:1000.

All exploration and operational workings (drill holes, trenches, dug pits, main trenches, adits/galleries, vertical mines/shafts, etc), detailed geophysical observation profiles, geochemical sampling profiles and points, and all types of natural outcrops are tied by geodetic measurements and plotted on contour maps. Using data of underground mining surveyor, the sites of underground excavation and underground boreholes are plotted to the Mining Horizon Maps. For bore holes, the coordinates of the points of intersection of roof and base of ore body and the extensions of their barrels/hollow space (estimating their curve or deviation) are plotted on exploration plan maps and sections. The exploration plan maps and mining horizon maps are usually produced at scales 1: 200 to 1: 500, unified underground surveyor maps – not less than 1: 1000 depending on the size of the deposit, geological settings and survey accuracy.

3.2. The geological structure of the deposit should be studied in detail and plotted on a geological map at scales 1:2000 to 1:10,000 (depending on the size and complexity of the deposit), geological sections, plan maps, underground horizons' maps and vertical (horizontal) projections.

The geological and geophysical survey materials of the deposit should give an idea of the size and shape of the phosphorite deposits, the conditions of their occurrence, reflecting their complexity including internal structure and continuity or discontinuity of beds, the characteristics of correlation between ore bodies and host rocks, influence of folded structures and tectonic faults to ore bodies in necessary and sufficient level of studies, become justified for the reserve estimation and resource evaluation. These data should also reflect the location of various types of ores, the structure of the top and base of ore bodies, changes of thickness along with strike and dipping direction, Mn contents and harmful impurities in the ore. It is recommended to define the geological boundaries of the deposit or mineralized zone based on the search criteria that determine the location of promising areas within which the determined resources are estimated.

The information and materials provided by the exploration of the deposit also determine the distribution of different types of ore in the deposit space, the surface and bottom of the ore body, the distribution of manganese and its associated beneficial and toxic components along the fall and elongation of the ore body. Exploration criteria have been identified, mineralization boundaries have been identified, and promising areas have been identified and evaluated. In order to meet this requirement, geological maps and mineral distribution maps of the ore district were developed on a scale of 1: 25000-1: 50000 (rarely 1: 10000) with relevant sections, which reflected the location of manganese mineralization complexes and ore control structures. The prospective sections are identified and the level of wealth is assessed.

The results of geophysical and lithochemical surveys, geophysical and geochemical anomalies associated with mineralization are identified and scaled in the geological maps and sections of the district.

3.3 Outcrops of ore bodies and subsurface parts of the deposit are recommended to be studied in detail, allowing determining the thickness and composition of the overburden, the position of ore bodies, degree of weathering, depth of the weathering zone development, and changes in the mineral composition and technological properties of ores. It has to be determined presence and degree of karsts development, tectonic faults and their nature. For this purpose, in addition to natural outcrops, it has to be conducted clearing works on ditches, digging pits and trenches, drilling shallow bore holes, as well as ground methods of geophysical survey.

3.4. Exploration of deposits of apatite and phosphorite ores to a depth is carried out mainly by rotary drilling using downhole logging and surface geophysics methods, and at a shallow depth poition of ore bodies – bore holes in combination with [surface] mine workings. A combination of borehole and excavation systems can be used to explore shallow ore deposits. In this case, the excavation is usually performed for the purpose of testing the results of the drilling, as well as for technological testing. Excavation is usually concentrated in the detailed study area for the primary mining of deposits and ore bodies.

Exploration methodology - the ratio of drilling and mining volumes, types of mine workings and drilling methods, geometry and density of the exploration grid, methods and methodics of sampling - should provide the ability to calculate reserves at explored deposits in reserve categories corresponding to the complexity group of the geological structure of certain deposit. It is determined based on the geological features of the deposits, taking into account the capabilities of mining, drilling, geophysical tools for exploration, as well as the experience of exploration and development of deposits of a similar type. When choosing the optimal exploration option, comparative technical and economic parameters and the timing of work on various exploration options are taken into account.

3.5 Exploring bore holes have to penetrate apatite or phosphorite beds in full thickness and deepening into the underlying rocks, depending on geological factors. In those cases where there are indications for identifying other horizons of manganese-bearing rocks in the underlying rocks, a small part of exploration bore holes should cross the entire section of these rocks. In the exploration of steeply dipping ore bodies, to obtain their intersections at large angle, it will be useful inclined bore holes, artificially curved boreholes and drilling of multilateral holes.

The practice of geological exploration has established that the core recovery from the ore body must be at least 90% for each drilling run. It is recommended to systematically control the reliability of the linear output of the core by other methods - by weight or by volume. The maximum possible yield of a well-preserved core should be obtained from rotary drill holes, which makes it possible to determine the bedding condition of ore bodies and host rocks, their thickness, the internal structure of ore bodies, the distribution of natural varieties of ores, their texture and structure, and to ensure the representativeness of the material for sampling.

The representativeness of the core for determining the content of manganese pentoxide and the thickness of ore intervals is confirmed by studies of the possibility of its selective abrasion. To do this, it is necessary to compare the results of core sampling (if necessary, and slime) for the main types of ores by intervals with its different core recovery.

It is allowed to use boreholes of smaller diameter, subject to the use of neutron activation and gamma ray logging to determine the Mn content and confirm the reliability of nuclear physics methods. In this case, large-diameter boreholes are drilled in the amount necessary to control the geophysical sampling data and take bulk samples for pilot test. When exploring ore bodies composed of loose ores, it is recommended to use a special drilling technology that increases the core yield (drilling without fluids, short runs, the use of special drilling fluids, etc.).

To increase the reliability and information content of drilling data, it is recommended to use methods of geophysical surveys in boreholes, the rational complex of which is determined based on the tasks set, the specific geological and geophysical conditions of the field and modern capabilities of geophysical methods. The downhole logging complex, effective for identifying ore intervals and establishing their parameters, is performed in all boreholes drilled on the deposit.

In vertical boreholes with a depth of more than 100 m and in all inclined ones, including underground ones, the azimuth and zenith angles of the boreholes are determined and confirmed by control measurements no more than every 20 m. The results of these measurements are taken into account when constructing geological sections, plan maps of horizons and calculating the thickness of ore intervals. If there are intersections of borehole's barrel to mine workings, the results of measurements are verified by the data of Underground mine surveying reference/tying data.

3.6 Types of exploration workings, their location and distances between them (grid density) are determined in each individual case, taking into account following geological features of the deposit: the conditions of occurrence, morphology and size of ore bodies, the variability of their thickness, the nature of the distribution of individual types of ores and the capabilities of geophysical method use, as well as the proposed method for developing the deposit in future. With complex tectonics and presence of erosion on the deposit, it has to be determined the nature, spatial position and amplitude of faults, and contoured the erosion zones, etc.

Given in Table 4, the generalized data about the grid density used in Commonwealth of Independent States (GIS) for the exploration of deposits of manganese ores can be used in the design of geological prospecting works. For each deposit, based on the study of the features of the geological structure in the areas of detailing and a thorough analysis of all available geological, geophysical and exploitation data for this or similar fields, rational geometry and density of the grid of exploration workings are substantiated.

The Table 5 presents some data of the manganese deposits and ore bodies identified in Mongolia, their properties, abilities of ores for concentrating and processing activities, and some information about exploration that carried to them.

As the exploration of the deposit deepens, the information on the geological structure of the deposit increases, and the level of knowledge of the deposit increases, it is necessary to optimize the density of the deposit exploration grid on the basis of all types of research, exploration data processing and analysis. All geological, geophysical, geochemical and other survey data generated during the deposit exploration, as well as operational exploration and mining data, should be fully utilized to determine the density and mesh geometry of the deposit.

Table 4.

Information of exploration grid density used for phosphate ore exploration

Group of deposits	Characteristics of ore bodies	Distance between workings (m) for reserve categories					
		A		B		C	
		Along striking	Along dipping	Along striking	Along dipping	Along striking	Along dipping
I	Large sized, simple geological settings	100–150	100–150	200–300	200–300	600	600
II	Large sized, complex geological settings	–	–	200	200	400	400
	Layered and lens shaped ore, complex geological setting	–	–	50–100	50–100	100–200	100–200
III	Small sized, layer lens like shaped ore, complex geological settings	–	–	50–100	25–50	100	50–100
When estimating resources by exploration, the error reduction factor / coefficient is used by comparing exploitation and exploration data.Clarification: Depending on the complexity of geological settings of the deposit, the density of the exploration grid in the evaluated deposit will be 2-4 times denser than the Indicated category (C) for the probable resource (P) and will not necessarily be confirmed by boreholes.							

3.7 Detailed exploration will be conducted to confirm the reserves of other parts of the deposit. In the pre-feasibility study during the exploration period, the size and number of the detailed parts should be determined by the licensee and should be denser than the grid density used in other sections. The reserves in the deposits which refer to the group 1 are estimated by Proved (A) and Measured (B) or A+B categories, the reserves in the deposit referring to the group 2 are estimated by Measured (B). On the other hand, it recommends to use two times denser grids compared to C category grids for the deposits which belong to the group 3.

In the detailed study part, the location conditions of the ore body (bed), the shape and quality of the reserve estimated ore body are different from the others. The geological settings, ore quality, and mining-geological conditions may differ within from the range of the reserve estimated area, and in some cases for the entire deposit.

The data obtained from the areas that are under detailed study, will be used to represent the deposit as a whole, such as the complexity of the deposit, the density of the exploration grid related to its geological settings, the reliability of the sampling results, and the calculation parameters. Exploration in mining stages and extraction results are also adoptable for the same purpose as mentioned above. In reserve estimation on areas that subjected to survey in detail, the exploration grid has to ensure the density is sufficient to substantiate the optimal interpolation using geostatistical modeling methods like as inverse distance weighting, Kriging and others.

Density of exploration grid used in aluminium deposits of Mongolia

Table 5.

№	Name of deposit, location	Geology of ore deposit	Group of deposit	Excavation type	Distance between workings (m) for reserve categories			Reserve, resource, tn	Extraction methods and systems	Concentration method
					Proved (A)	Measured (B)	Indicated (C)			
1	***Khukh teeg deposit.*** Dundgobi prepecture, Undurshil	Contact metamorphysim between Oortsog farmasion and Permian granite, breccian lins like shape ore body. Main minerals pyrolusite, mnagnaite 20-25%, quarz 5-10%, carbonite 60-70%. Size: 185 x 105 x 6.8 м	III	Drilling and trenching	-	40-60	50-100	B+C 549.9 million tons of ore Mn-12% дундаж агуулгатай 66.1 мян.тн	Open pit	Wet magnetic
2	***Toli bulag deposit.*** Dornogobi prepecture, Mandakh	Oligocene-age unclassified gravelite and conglomerate sedimentary strata. Dimensions 83 x 43 x (2.2-4.3) m. The average thickness is 22 m. Mn-content 14.3%. manganite 30%, hydrogytite 2%, ore minerals are manganite-pyrolysite-goethite	III	Drilling and trenching	-	30-60	50-100	B+C 216.0 million tons of ore Mn-14.3% average content 30.9 th.tn.тн	Open pit	Dry magnetic
3	***Unagad deposit.*** Dornogobi prepecture, Airag	A trough-shaped ore body in the Lower Cretaceous Tsagaantsav Formation in gravel-sandstone, gravelite, and small gravel conglomerates. Dimensions: 1800 x 300 m. Thickness 4-5 m. Pyrolysite 90%, manganite 7%, psilomelan 3%	II	Drilling and trenching	-	100-80 x 50-40	200 x 100	B+C 4.1 million tons of ore Mn-8.35% average content 346.9 th.tn	Open pit	Twice with a magnetic separator

4	***Khurmen-II deposit*** Umnugobi prepecture, Bayandalai	It consists of manganese brown sediments located in harmony in the siltstone of the Gurvansaikhan formation of the Middle-Upper Devonian. The total length of the deposit is 2000 m, thickness 50 m, The main minerals are pyrolysite 90%, manganese 8-13%,	III	Drilling and trenching	-	100 x 20-40	-	B+C 934.2 million tons of ore Mn-13.7% average content 128.2 th.tn, P_1=98 th.tn.	Open pit	Twice with a magnetic separator
5	***Burged khar uul deposit.*** Dornogobi prepecture, Khatanbulag	Limestone-type limestone with manganese mineralization in the upper part of the carbonate-sedimentary layer of the middle eagle black mountain formation contains manganese mineralization. The mineralized zone is composed of tectonics. The length of the ore bodies is 1200 m, the width is 150-300 m, the thickness is 0.4-40 m.	III	Drilling and trenching	-	100 x 50	-	B+C 7.63 million tons of ore Mn-7.8% average content 594.2 th.tn	Open pit	Dry magnetic
6	***Khuren Tolgoi deposit.*** Umnugobi prepecture, Khankhongor	11 ore bodies were identified in the Central and Eastern 2 sections. The reddish-brown, solid-textured, siliceous siltstone, argillite, and fine-grained quartzite-layered strata were elongated by ZU-1600 and collapsed by 60-650. 200 m wide, 600 m long, concreted in the form of concrete, nest-like narrow veins, inlaid mineralization.	III	Drilling and trenching	-	100 x 50	-	B+C 1.75 million tons of ore Mn-19.2% average content 336.2 thousand.tn	Open pit	

3.8 Each drillhole and excavation result must be documented. It is recommended to take photos if the ore body is characterized by different colors. The roof, walls, sampling workface, and dip and strike extension must be documented; specially appointed commission has to monitor completeness and quality of primary geological documentation, which meets compliance with deposit's geological features, correctness of determination of the spatial position of the structural elements, the preparation of sketches and their descriptions in the prescribed manner. Furthermore, it should be controlled and assessed quality of geological and geophysical sampling (consistency of cross-section and weight of samples, their position corresponding to the peculiarities of the geological structure of the deposit, the completeness and continuity of sampling, the presence and results of control testing), the representativeness of mineralogical and engineering-hydrogeological studies, the determination of volume weight, sample processing and quality of analytical work.

3.9. It is crucial to take samples from each interval identified both in the natural outcrops and resulted from exploration to study the mineral quality, reveal the contact or boundary of the ore body as well as estimate its reserves. The sampling result must be reported in geological description and included in primary documentation.

3.10. The proper choice of geological and geophysical sampling methods is based on geological characteristics and geophysical properties of both host hocks and target minerals during the initial stage of geological survey and evaluation. The selected method or technique must be the most effective, economically efficient and guaranteed for expecting result.

In case of using a number of sampling methods, derived results and accuracy should be compared and assured. It is necessary to follow relevant standard and methodology on sampling method selection (core drilling, trenching, and stripping) to determine the processing quality and evaluate the assurance for the sampling method.

3.11. The following conditions should be considered in the sampling of exploration sections. These include:

- The sampling grid should be stable across the exploration section and the density of the grid should be determined in accordance with the geological formation of the part of the deposit being tested.

- The specimen should be placed in the direction of maximum mineralization. If there is any doubt as to the reliability of the results when the ore body is sampled by excavation (especially borehole) with a maximum angle of inclination, use the results obtained in the control calculation (eg, in the case of highly variable excavations). , whether to resolve the issue.

- Sampling of the exploration section shall be carried out continuously in certain steps. In addition to the thickness of the ore body being sampled, the ore body shall be completely penetrated to a certain extent (equivalent to the thickness of the empty rock and non-standard ore body that may be included in the reserve).

- Weathered parts of the ore body, natural types of ore and mineralized parts of the host rock shall be separated and tested separately.

- The length of the test step (section) along the exploration section shall be determined based on the internal structure of the ore body, distribution of minerals, changes in grade, ore structure, texture characteristics, physical and mechanical properties of the ore and other parameters (eg excavation and drilling progress length).

- The most commonly used test step length for manganese deposits is 1.0 m, and in rare cases 2.0 m. However, in determining this value, the characteristics of the distribution of minerals in the ore, the non-uniformity of the composition and structure of the ore, the characteristics of the distribution of different granular ores, and the specific gravity of the ore (portion contrast of the ore) are taken into account.

- Parts with different core outputs shall be sorted and tested separately.

- In addition to taking samples from the core where the core is subject to selective wear, the powder and turbidity sludge generated during drilling will be sampled separately and processed separately for analysis.

- The results of nuclear geophysical sampling (logging) shall be developed in steps of 5-10 cm in proportion to the size of the rock granules, following the methodology relevant to their natural conditions.

3.12. Regular control and evaluation in accuracy and relability is required in quality of each sampling method and techniques used for main ore types. The interrelation between theoretically defined and present weights is monitored on the basis of the sample characteristics compared with the elements of geologic settings, preciseness of identified contact or boundary of ore body, theoretically expected size and real size of the taken ore, core sample diameter, and total recovery (the range can be no more than ±10-20% depending on ore density).

Trench sampling accuracy is controlled by sampling from a trench which lies adjacent to the target trench and is with the same diameter; ore sampling accuracy is controlled by taking duplicate core samples from the rest half of the borehole. Precision of geophysical acquisition completed in the natural outcrops is examined by instrument stability and results of normal and controlling measurement conducted under the same condition.

The accuracy of geophysical data acquisition is provided by comparing geological and geophysical data resulted from interval sampling with good recovery (95% or more) of core which is not weathered. If an error detected, logging and sampling repeated. To do this, technological samples, bulk samples and mining results can be used.

The amount of samples for controlling purpose must be sufficient for making statistical analysis to reveal random or regular error, and determining correction quotient if necessary.

3.13 Sample processing should follow the circuit scheme adopted by analogy with similar deposits. Both main and duplicate samples are processed in accordance to the same scheme. Processing quality, procedure implementation and reasonable condition for using ration “K” must be regularly controlled. Control processing of large-volume samples is made according to specially designed program. The chemical composition of ores should be studied with completeness, providing a reliable assessment of their quality, the identification of harmful impurities and useful associated components. The content in the ore is determined by chemical, magnetic, nuclear-physical, other geophysical, spectral and other methods of analysis established by state standards.

3.14 The chemical composition of the ore should be studied at the level of primary and secondary minerals, toxic impurities that adversely affect the quality of the mineral, and slag / slag generating plants. Their content in manganese ores shall be determined by chemical, physicochemical, geophysical and other methods in accordance with the approved methods and standards for the analysis of ore and rock composition. The use of geophysical methods in the study of manganese ore composition, the use of innovative methods, and whether their results can be used in the calculation of deposit reserves will be decided based on the conclusion of a specially appointed expert organization.

The study of accompanying components contained in manganese ore is carried out in accordance with the "Recommendation for the integrated study and reserve estimation of accompanying useful components". As such kind of recommendation has not yet been developed, therefore similar recommendations can be used, such as the Russian “Methodological recommendations for the comprehensive study of deposits and reserve estimation of accompanying mineral resources and components” developed in 2007.

Determination of manganese (Mn) and phosphorus (P) content in all manganese ore samples, analysis of manganese dioxide (MnO_2) in manganese oxide ore, determination of iron (Fe) and manganese (Mn) content in iron-manganese ore was analyzed.

Analysis of manganese ore by-products, toxic compounds, and slag / slag-forming plants is usually performed on grouped samples. The method of aggregation of simple samples into grouped samples and the selection of grouped samples are based on the selection of auxiliary minerals, toxic impurities, slag / slag-forming plants in the ore evenly distributed in the ore body space depending on all natural types of ore. The choice is made to allow for the identification of

Phase analysis of the ore to determine the degree of oxidation of manganese ore.

3.15 Geological control on sample analyzes has been carried out independently of laboratory control, during the entire period of exploration of the deposit. The results of analyzes for all main and accompanying components and harmful impurities are subject to control. All samples with extremely high content must be subjected to the internal control.

3.16 The external control that completed to identify and evaluate possible systematic errors is carried out to a laboratory that has a control status. Duplicate analytical samples are sent for external control, stored in the main laboratory and passed internal control. For the systematic control of the work of the main and control laboratories, it is needed reference samples (composed of ores of deposits) and standard samples composition (SSC), which are included in encrypted form in batches of analyzed samples.

Samples to be sent for internal and external inspection of samples shall cover all types of natural ore of the deposit, all groups of mineral content, and samples with high content shall be included in the control.

3.17 The volume of internal and external control on the sample analyzes should ensure the representativeness of the samples for each grade class from all varieties of ores of the deposit and periods of analysis. The standard requirements shall be taken into account in determining the grade class of useful mineral in the sample. With a large number of analyzed samples per year (more than 2000), 5% of their total number is sent for control analyzes, with small batches of samples for each distinguished grade class, at least 30 control analyzes are performed for the control analyzes in reference period.

3.18 The processing of internal and external control data for each grade class is carried out by periods (quarter, half year, year) separately for each method of analysis and the laboratory that performed the main analyzes. And based on the assessment of internal and external control data, the discrepancies and errors should be corrected.

The random standard deviation of a value of sample analyzes, determined by the results of internal control, should not exceed the values given in Table 6.

Table 6.

The allowable relative value of standard deviation for the analyses results on manganese ore content

Compo nent	Class of ore content, %,	allowable relative deviations *	Component	Class of ore content, %,	Allowable relative deviations *
Mn	>22	1,2	Al_2O_3	10–15	5,0
	13–22	2,0		5–10	6,5
	5–13	2,5		1–5	12
	3–5	3,5	CaO	20–40	2,5
	0,5–3	6,0		7–20	6,0
	0,2–0,5	10		1–7	11
Fe	30–45	2,0	P_2O_5	0,3–1	5,5
	20–30	2,5		0,1–0,3	8,5
	10–20	3,0		0,05–0,1	12
	5–10	6,0		0,01–0,05	22
SiO_2	20–50	2,5		0,001–0,01	30
	5–20	3,5	S	1–2	9
	1,5–5	11		0,5–1	12
				0,3–0,5	15
* If the specified limits are exceeded, the basic analyzes results of a certain class and the times of their performance are rejected and it is subjected to re-analysis and control. At the same time, the main laboratory identifies the causes of defects and takes measures to eliminate them.					

3.19 If systematic discrepancies are confirmed by the external control data between the analyzes results of the main and controlling laboratories, arbitration control should be dispatched about 30 to 40 samples from each sample group, in which systematic discrepancies are revealed, into repeating analyzes. If an arbitration laboratory analyses reveal systematic / persistent errors, the issue of whether to use a correction coefficient to the results of basic analyses of the samples has to be resolved. At the same time, measures should be taken to identify and eliminate the cause of systemic / persistent errors in the laboratory where the main samples were analyzed.

If a systematic / persistent error is detected by analyzes involving standard sample content, 10 to 15 standard samples will be analyzed in an arbitration laboratory to determine the error and take action to correct it.

Without arbitrage analysis, the introduction of correction coefficient is not allowed.

3.20 Based on the data from the sampling, processing, and analysis of the samples, the ore intervals will be separated, the enclosure will be made, and its size and location will be assessed to determine how accurately and accurately it is.

3.21 The composition, structure, texture, and physical-mechanical properties of the ore mineralogy shall be studied using mineralogical-petrographic, physical, chemical, and other analytical methods in accordance with established methods and techniques.

In the study of manganese ores, special attention is paid to the identification of manganese minerals, their content, quantity, coexistence of ore minerals with each other and other minerals, mutual location, co-growth characteristics of mineral crystals, manganese grain size and distribution characteristics. . It also provides descriptions of ore mineral concretes and oolites, and clarifies the stratigraphic structure and composition of the ore. In the case of ores with concrete, oolite and conglomerate formations, their cement properties should be described as sandy, loamy, loosely bound powder, or hardened.

During the chemical and mineralogical study of manganese ore, the distribution characteristics of manganese ore minerals were determined, as well as the distribution characteristics of manganese and its constituents, beneficial and toxic compounds, and slag / slag-forming compounds.

3.22 Volume weight/density and moisture content of ore are representing important parameters for reserve estimation; therefore, they should be determined for each natural variety of ore, and layer / plies with substandard thickness or gangue rocks within the ore body. The volume weight/density of massive ore is determined mainly from representative waxed samples via hydrostatic weighing method. It is more reliable to determine the volume weight of loose, highly fractured and cavernous leached ore by comparing the weight of the excavated ore with the well-measured excavation volume.

Determination of the volume weight can also be completed by the method of absorption of scattered gamma radiation in the presence of the necessary amount of verification work. Simultaneously with the determination of the volume weight, the moisture content of the ore is determined on the same material. Samples and specimens that used for determination of volume weight and moisture are recommended to be characterized mineralogically and analyzed for the main components.

3.23 As a result of studying the chemical, mineral composition, textural and structural features and physical properties of ores, natural varieties of ores should be established and industrial (technological) types and grades subject to separate excavation, requiring different processing methods or having different areas of use should be preliminarily outlined.

The final selection of industrial (technological) types and grades of ores is made based on the results of technological study of the natural varieties identified at the deposit in the process of geological and technological mapping.

Four. Studies on technological property of ore processing

4.1. Depending on the type of manganese ore production (technology), the mineral processing method is selected. The technology tested based on the results of mineral composition and analysis.

For all industrial (technological) types of manganese ores, the radiometric and stadial gravity-magnetic enrichment scheme is the basic one. It uses the principle of "sparing" technology, which consists in the isolation and preservation during ore processing of a large-lump product that meets the requirements for the charge in the smelting of manganese alloys in terms of quality and granular composition. The chemical composition of the ore is determined by modern high-precision instruments such as induction-coupled plasma-mass spectrometers, atomic absorption spectrometers, induction-linked plasma optical emission spectrometers (ICP-OES, ICP-MS). X-ray fluorescence analysis (XRF) of the wave dispersion also identifies 44 elements. Detailed ore mineral analysis will be performed using X-ray diffractometer XRD, TESCAN-TIMA mineral analyzer, and Mineral Liberation Analysis (MLA) instruments. These methods of analysis not only determine the composition of high-grade minerals, but also determine the content of very low-grade impurities.

Manganese ore beneficiation technology will be based on the principle of sorting and storing coarse-grained products capable of meeting the requirements for manganese alloy mixtures (grains) in terms of quality and particle composition.

4.2. The technological research of ores should be preceded by the study of the possibility of radiometric large-batch sorting of the extracted ore mass in transport containers. Preliminary forecast technological indicators are obtained by calculation when processing the data of testing or logging in the technological circuits of operational units. In accordance with the relevant methodological documents, the portion contrast of ores of the selected natural varieties, physical signs that can be used to separate the ore mass should be established, radiometric sorting indicators for portions of different volumes should be evaluated. For experimental confirmation of technological indicators of large-batch sorting, experimental mining operations are carried out with express analysis of the ore mass in transport tanks at the ore control station (RCS) and sorting into conditioned, substandard ore and dump rock. The reliability of the express analysis of ore in transport containers and the quality of the sorting products must be certified by a control gross sampling.

With positive results, it is necessary to clarify the industrial (technological) types of ores that require selective extraction, or to confirm the possibility of gross extraction of ore mass, to clarify the parameters of the mining system, as well as to determine the possibility of obtaining grades of rich ore.

4.3. Technological properties of ores, as a rule, are studied in laboratory and semi-industrial conditions on mineralogical, small technological, laboratory, enlarged laboratory and semi-industrial samples. With the existing experience of industrial processing for easily enriched ores, it is allowed to use an analogy confirmed by the results of laboratory studies. For difficult-to-enrich or new types of ores that have no experience in processing, technological studies of ores and, if necessary, products of their enrichment should be carried out according to special programs agreed with interested organizations.

Sampling for technological research at different stages of geological exploration should be carried out in accordance with the standard of the Russian Geological Society - STO RosGeo 09-001-98 "Solid minerals and rocks. Technological testing in the process of geological exploration", approved and put into effect by the Decree of the Presidium of the Executive Committee of the All-Russian Geological Society.

4.4. All-natural varieties of ores identified at the deposit should be characterized by mineral-technological and small technological samples. According to the results of their tests, geological and technological typing of the ores of the deposit is carried out with the allocation of industrial (technological) types and geological and technological maps, plans and sections are compiled. When carrying out geological and technological mapping, one should be guided by the standard STO RosGeo 09-002-98 "Solid minerals and rocks. Geological and technological mapping", approved and put into effect by the Decree of the Presidium of the Executive Committee of the All-Russian Geological Society.

Technological properties of all selected industrial (technological) types of ores are studied on laboratory samples to the extent necessary to select the optimal technological scheme of their processing and determine the main technological indicators of enrichment.

Enlarged and semi-industrial technological samples are used to verify technological schemes and refine the indicators of ore enrichment obtained from laboratory samples.

Large-scale laboratory and semi-industrial technological samples should be representative, i.e. meet the chemical and mineral composition, structural and textural features, contrast, physical and other properties of the average parameters of ores of this industrial (technological) type, taking into account possible dilution during mining and an increase in the content of components in the ore after large-batch sorting. According to the granulometric composition, the samples must correspond to the beaten-off ore mass of the adopted mining system.

4.5. For ores with a high yield of lump fraction -200+10 mm, dry enrichment schemes with radiometric separation of classes -200+10 mm and magnetic separation of class -10 mm can be used.

Radiometric enrichment studies are carried out on samples of the accepted source ore in accordance with the relevant methodological documents and include: determination of the granular composition of ore after large crushing with an assessment of the distribution of metal by class; study of contrast and enrichment with optimization of the separation feature; experimental evaluation of technological parameters of radiometric separation with the production of lump manganese concentrate, dump tailings and industrial products sent together with screening (class -10 mm) for processing by traditional enrichment methods (gravity, magnetic separation); selection of industrial equipment. The material composition of the enrichment products is being studied.

4.6. When studying the initial ore or industrial product of radiometric separation and screening, using methods and techniques of technological mineralogy, the degree of their oxidation, mineral composition, structural and textural features, as well as physical and chemical properties of minerals and mineral complexes, the degree of contrast of these properties are studied. The fractionability, the degree of disclosure of mineral phases, ore washability are determined, sieve and gravity analyses of narrow classes of washed ore and washing sludge, magnetic analysis of small classes are carried out.

4.7. A specific feature of manganese ores is the variety of mineral forms of manganese, as well as extremely uneven inclusions of ore minerals ranging in size from fractions of a millimeter to several centimeters. As a result, traditional schemes for the enrichment of manganese ores, which are based on the principle of extracting a valuable component as it is disclosed, are branched and multi-stage. Ores are enriched according to gravitational, gravitational-magnetic and gravitational-magnetic-flotation schemes.

When developing the scheme, they provide:

– washing, screening and crushing of ore;

круп large-batch enrichment of classes +10 mm by heavy-medium separation or large-batch jigging to obtain lump concentrates of various grades and industrial products;

обогащ enrichment of initial grades -10+1(0.5) mm and crushed industrial products of coarse-grained enrichment by magnetic separation in high-intensity fields (~ 750 kA/m) or by depositing to obtain fine-grained concentrate, industrial products and dump tailings (the size of the material is specified for a specific ore depending on its properties);

глубокое deep enrichment of small grades of initial ore, low-grade industrial products of gravity-magnetic enrichment, finely ground to a size of -25(16)+1(0.5) mm, and sludge washing by high-gradient magnetic separation or flotation to obtain fine-grained concentrate and dump tailings.

Flotation is carried out using fatty acid collectors: raw tall oil, naphthenic and technical fatty acids, sebacic acid production waste, etc. The supply of reagents in the form of emulsions or soap together with petroleum products (diesel fuel, salt oil, emulsifier, fuel oil, etc.) increases their collecting capacity. Soda and caustic soda are used as reagents – regulators of the medium. Liquid glass is used for the depression of waste rock minerals. Flotation is preceded by desalination according to the class -15 microns. According to the collective flotation scheme, oxides and carbonates are flown together. According to the selective scheme, carbonates are floated in the presence of liquid glass at low collector costs (up to 0.05 kg/t), then with increased collector supply (up to 3 kg/t), manganese oxide minerals are floated. To enrich a larger material -1 (0.5) mm, foam separation is used, which is carried out with the same reagents.

Dephosphorization is carried out by the gausmanite method according to the scheme, which includes firing at 900 ° C and leaching the stub with a dilute solution of nitric acid at room temperature to obtain a conditioned oxide concentrate.

4.8. Promising methods of processing manganese ores:

- large-batch sorting in transport containers as a key element of the quality management system;

- bulk combined radiometric (X-ray radiometric and X-ray luminescent) separation, which releases a large-lump product that meets the requirements for the charge in the smelting of manganese alloys in terms of quality and granular composition;

- magnetic separation with a high-intensity magnetic field for processing material with a size of -10 mm using electromagnetic rotary separators, which allows to obtain a marketable product with a significant simplification of the technological scheme by eliminating crushing operations and ore classification;

- flotation with preliminary selective coagulation or flocculation of manganese minerals, which makes it possible to reduce losses during deslamation (emulsion or column flotation);

processing of carbonate manganese ores, especially those that are difficult to enrich, according to the "firing – direct alloying" scheme during the smelting of mass-purpose steels; the resulting complex product contains an alloying element and an effective flux;

- hydrometallurgical processing, including:

a) sulfate method of leaching manganese from ores and concentrates with a solution of sulfuric acid when heated, or decomposition of ores by the dithionate method by saturating an aqueous suspension of ore or sludge with sulfur dioxide at 80 ° C to produce manganese sulfate – a semi-product for the production of CDM, EDM, MnO_4; the dithionate method is not suitable for processing mixed manganese ores;

b) ammonium method of manganese leaching with ammonium carbonate after preliminary reduction firing at 750-800 ^{o}C;

c) soda method of extracting manganese from poor carbonate ores by treating them in an aqueous suspension with carbon dioxide under pressure with the transfer of manganese carbonates to soluble bicarbonate;

d) chemical leaching, including mine, borehole and heap leaching with dilute solutions of sulfuric and hydrochloric acids;

e) biochemical leaching, used for the treatment of low-quality ores, enrichment waste, sludge, the processing of which by traditional methods is ineffective.

Various groups of microorganisms are present in mineral deposits, the geochemical activity of some of them consists in influencing minerals with the help of a huge arsenal of reactive metabolites synthesized by them (metabolic products) that convert metals into a soluble state in the form of intra-complex compounds (chelates). The latter are resistant to precipitation and have mobility in a wide pH range.

Biochemical leaching of manganese from mixed and carbonate ores is carried out by the vat method. The leaching reagent is the products of the metabolism of acetobacteria. Manganese is released from the productive solution by chemical precipitation or electrolysis. The extraction of manganese into the solution during biochemical leaching is more than 90%.

4.9. As a result of the conducted research, the correctness of geological and technological typing of ores should be confirmed:

(if necessary, geological and technological mapping is reinterpreted), the mineral and chemical composition of the initial ore and enrichment products are determined, data on washing, crushing, crushing of ores and the required degree of grinding of the material, data from sieve analyses of the initial ore and products are presented enrichment, information on the density, bulk weight and humidity of the initial ore and enrichment products; technological indicators of processing have been established: for radiometric enrichment – the yield of concentrate, industrial products and tailings, the extraction and content of manganese and associated components in them, the enrichment coefficient; for gravity, magnetic separation and flotation processes – concentrate yield, its quality (content of manganese, other useful components and harmful impurities), concentrate processing method, extraction of manganese and other useful components in separate operations and their end-to-end extraction, reagent consumption, volume and characteristics (granular composition, residual concentration of reagents) of products, sent to the tailings dump, the need and methods of neutralization of industrial effluents.

The reliability of the data obtained as a result of semi-industrial tests is evaluated on the basis of technological and commodity balance. The difference in the mass of metal between these balances should not exceed 10%, and it should be distributed proportionally to the mass of metal in concentrates and tailings. Processing indicators are compared with those obtained at modern processing plants and GMZ for processing manganese ores.

4.10. There is no unified state standard or technical specifications for manganese ores. The quality of concentrates in each specific case is determined by the contract between the supplier and the consumer.

Depending on the purpose, different requirements are imposed on manganese concentrates. Concentrates and agglomerates used by the metallurgical industry are normalized by the content of manganese and harmful impurities (phosphorus, silica, iron), as well as by the content of fines (8-0 mm) and large pieces (+25 mm).

When assessing the quality of the intended products of processing processing, it is possible to be guided by the requirements for concentrates, peeled and agglomerated products listed in the reference book "Mineral raw materials. Manganese" (M., 1998).

In the established domestic practice, it is considered that the quality of manganese raw materials must comply with the standards specified in Table 7.

Table 7.

Qualitative characteristics of manganese raw materials

Direction of use	Характеристика марганцевых концентратов, %					Humid ity,%	Granular composition, mm
	Mn	MnO_2	SiO_2	P	S		
Ceramics	45–47	70–75	–	0,15	0,03	–	–
Glass containers	49–50	70	Not limited	–	–	2	–5
Dark green glass	50–54	70–73	–	–	–	–	–5
Enamels	–	80–82	–	–	–	–	Fine grinding
Dyes	45	–	10	0,20	0,1–0,3	–	0–25
Potassium Permanganate	56,2	89	3	–	–	8	0,10
Chemical current sources	–	87	–	–	–	3	–
Incendiary masses	45	90	7	Not limited	–	8	0,10
Welding fluxes	49–50		–	0,18	–	–	20

4.11. For associated components, in accordance with the "Recommendations for the comprehensive study of deposits and calculation of reserves of associated minerals and components" approved by the Ministry of Internal Affairs of Russia in accordance with the established procedure, it is necessary to find out the forms of finding and balance of their distribution in the products of enrichment and conversion of ores and concentrates, as well as to establish the conditions, possibility and economic feasibility of their extraction.

The possibility of using recycled water and waste obtained according to the recommended technological scheme should be studied: the processing of sludge for micro-fertilizers, the use of industrial products for the enrichment of manganocalcite composition for the production of premixes used as feed additives in agriculture; recommendations are given for the cleaning of industrial waste.

Construction, ceramic, paint and varnish industries, agriculture, etc. can be considered as consumers of mining and enrichment waste.

Five. Studies on hydrogeological, engineering-geological, geo-ecological and other natural conditions of deposit

5.1. Studies on hydrogeological condition of the deposit should be conducted in accordance to “Guidelines for hydrogeological survey on thematic studies, hydrogeological mapping at medium-large, scales and of hydro-geological survey during mineral deposit exploration and the requirements to them” approved by the Order No. A / 237 of the Minister of Mining and Heavy Industry of Mongolia dated December 12, 2017.

5.2. Hydrogeological study should determine the main aquifers that can participate in the watering of the field identify the most waterlogged areas, zones and resolve the issues of using or discharging mine waters.

5.3. For each aquifer, its thickness, lithological composition, types of reservoirs, recharge conditions, relationship with other aquifers and surface waters, position of groundwater levels and other parameters should be established; to identify possible water inlet into the exploiting of mines, which are included in the feasibility study of conditions, and to develop recommendations for their protection from groundwater. It is also necessary to:

- to determine hydrogeological parameters of water-bearing rocks (infiltration coefficient, water permeability coefficient, level permeability coefficient, water debt, etc.) by drilling and pumping hydrogeological boreholes;
- to study the chemical composition and bacteriological state of the water involved in the flooding of mine, their aggressiveness toward concrete, metals and polymers, the content of useful and harmful impurities in them; for the developing deposits - clarifying the chemical composition of mine water and industrial waste;
- to assess the possibility of using drainage water for the water supply or extracting valuable components from it, and possible impact of drainage on groundwater intakes in the surrounding area;
- to make recommendations for carrying out the necessary special prospecting work in the future, and to assess the impact of the discharge of mining waters on the environment;
- to assess possible sources of supply of drinking water and technical water supplies to meet the needs of future mineral extracting and ore processing plants.
- in case of utilization of drainage water, it should be calculated its exploitational reserves in accordance to the relevant regulations and methodological documents.

5.4. Hydrogeological studies should provide recommendations for the design of the mine on dewatering the mineable ore body, drainage system reservoir, drainage water utilization, water supply sources and environmental protection measures.

5.5. During exploration works on deposit, study of engineering-geology and geotechnical conditions should have been obtaining information for the development of the project in accordance to relevant methodical recommendations. In the absence of such kind of recommendations, similar recommendations can be used like as Russian “Methodological Guidelines for the Study of Engineering-Geological Conditions of Mine Exploration, 2000”, “Engineering-Geological, Hydrogeological and Geo-ecological Studies in Exploration and Exploitation of Ore Deposits, 2002”.

Engineering-geotechnical exploration will be included in the engineering-geological survey and will be implemented within the framework of the General Basic Norms and Rules for Construction Engineering Research approved by the Order No. 138 of the Minister of Construction and Urban Development in 2019.

5.6. Engineering-geological surveys that being carried out to deposit during exploration, should create the conditions for determination of key parameters of mines, underground excavations and shaft pillars; preparing the passports (special certificates) for drilling and blasting works and mine fastening works in underground mine excavation, and to create safe and accident-free conditions for future mining operations.

The following issues will be identified by the engineering-geological survey of the deposit. These include:

- physical-mechanical properties of graphite ores, host rock and overburden, determining their strength in natural and water-saturated states;
- engineering-geological features of the host rock that forming the deposit and its anisotropy, rock composition, texture specification, suffering fractures and tectonic faults;
- destruction of rocks due to karst and physical-mechanical properties and state of the rocks in the weathering zone;
- the possibility of landslides, mudflows, avalanches and other physical and geological phenomena that can complicate the mine development.

5.7. As a result of the geological survey, the deposit engineer will assess the stability of future underground excavations and quarry walls and identify key indicators for the optimal selection of key parameters. The methods of exploitation are applied depending on the mining and geological conditions of the ore bodies, the accepted the mining-technical schemes and the standard mining factors, which is calculated on the basis of the Technical-Economical feasibility condition.

5.8. Manganese deposits are operated by open pit and underground mine. The complex of underground mining can include modern methods such as underground leaching of manganese ore (GDL) and borehole hydraulic (DHG) mining.

For selective open and underground manganese mining, priority is given to the selection of equipment to minimize the yield of ultrafine fractions, which are often associated with rich manganese ores.

In mining, modern preferred methods, such as borehole leaching (DHL) and borehole hydraulics (DHW), are often used to extract ore with poor but high reserves, or deposits with very complex mining and geological conditions. Underground borehole leaching (DLC) is effective in the extraction of manganese carbonate ores and mixed ore fragments.

The use of this method in the extraction of manganese dolomite ore gives better results than in the extraction of manganese ore in limestone. This is because the solution formed by leaching manganese ore reacts with limestone to form gypsum, which in turn fills cracks and pores in the rock and impairs its permeability.

Products rich in manganese (50–53% Mn), manganese carbonate ($MnCO_3$), metallic manganese (Mn) and manganese dioxide (MnO_2) can be obtained from the working solution obtained by this method. An underground leaching experiment with boreholes at the Polunochi group of manganese carbonate ores in the Ural Lake in Russia's Sverdlovsk Oblast has yielded good results and found that the construction of a leaching plant could save time and cost less than underground mines and quarries. In addition, leaching has the advantage of ensuring labor safety and producing low-cost, high-quality products.

The borehole hydraulic (MW) extraction method is more suitable for the extraction of oxidized, brittle, powdered and semi-powdered manganese oxides and manganese silicate ores. In this case, manganese ore borehole hydraulics (HMD) have the advantages of underground and open pit mining methods, which are more cost-effective and less time-consuming to build.

The combination of underground leaching (DHL) and borehole hydraulic (DHW) mining methods, as well as underground mining and quarrying, can increase the depth of mining and increase economic efficiency. When these methods are used in succession for manganese silicate and carbonate ore deposits, it is possible to fully mine the ore, reduce the cost of producing the commodity, and save costs.

During the exploration phase, the following issues of future mining companies will be studied and optimal options will be proposed. These include:

- Selection of mining methods and systems.

- Selection of mining equipment, mechanization, automation, mining plant capacity.

- Mining and processing waste and pollution and ways to reduce it.

- Quarry bench height, wall stabilization angle, open pit and underground penetration depth.

- Standard parameters such as marginal grade, low production grade and low thickness surrounding the ore body, high thickness of hollow rock within the reserve, stripping and its limit value.

The choice of a rational mining system of the deposit is made on the basis of the results of technical and economic analysis providing options of development schemes and technological schemes for the graphite ore processing.

5.9. The following issues have been identified in the environmental study. These include:

- Baseline parameters of groundwater and surface water, soil, vegetation, fauna and atmosphere.

- Adverse physical and chemical effects of the establishment of mining plants on the environment, such as contamination of adjacent areas, contamination of surface and groundwater discharged from the mine, and contamination of soil and vegetation from mining operations.

- The amount of natural resources to be used for mining purposes, such as industrial forest use, water supply for technical and domestic use, construction of main mining plants and ancillary facilities, stripped soil, concentrator waste, and non-compliant ore stockpiles.

- The intensity, severity, dynamics, duration, and extent of the impact of mining operations on the environment were assessed and assessed.

In order to fully rehabilitate the soil, the thickness of the soil layer will be determined, agrochemical studies of the soil and loose sediments will be carried out, and the environmental impact of the stripped soil and rocks will be studied and the possibility of vegetation cover will be established.

5.10. The types, scope, and implementation of environmental protection activities to be carried out in highly complex hydrogeological, engineering, geological, and geo-ecological areas that require special environmental protection activities are based on programs and collective agreements developed by the miners in consultation with the project organizations.

5.11. A study was conducted to identify non-mineral areas in depth in order to select the location for the construction of industrial and civil facilities, stripped soil, non-standard grade ore, and concentrator tailings in the area where new mining plants have been established.

5.12. In the case of deposits containing natural gas such as methane and hydrogen sulfide in sediments and rocks, the patterns of changes in the composition and content of gas components have been studied in the surface and in the aquifers.

5.13. High levels of radiation, respiratory and pulmonary effects (pneumoconiosis), geothermal conditions and other natural effects on human health have been identified.

5.14. The study of manganese-bearing rocks and other minerals contained in the sediments was conducted in accordance with the requirements of the “Comprehensive study of mineral deposits and guidelines for estimating associated mineral resources” and determined their production value and scope of use.

5.15. Geological exploration of the deposit, study of possible archeological, historical monuments and paleontological finds within the boundaries of the mining area and future districts to build future mining and processing plants shall be carried out in accordance with established procedures and guidelines.

Six. Ore reserve estimation and resource evaluation

6.1. Reserve estimation and resource evaluation of graphite deposit are completed in accordance with the Mongolian “Classification and Guidelines of Mineral Resources and Reserve estimation of Deposit, 2015”.

6.2. Reserves of certain deposit are calculated on blocks, whose ore reserves should not normally exceed the annual production capacity of a future mine. The ore bodies allocated to the reserve estimation blocks shall be characterized by:

- the same level of exploration and study of the parameters determining the quantity and quality of ores;
- the homogeneity of the geological structure, approximately the same or similar degree of variability in thickness, the internal structure of ore bodies, the material composition, the basic quality and technological properties of the ore;
- stable bedding conditions for the manganese bodies, defined by block location with a single structural element (limbs, part of fold axis, tectonic block, limited by disrupting faults); and
- common condition for mining-geological development.

The reserve blocks will be limited to the mining horizon along with the ore body dipping direction or to boreholes, considering on the sequence of future mining operation.

6.3. The reserve estimation of the deposit has to consider following additional conditions, reflecting the specificity of graphite ore deposits.

The proved (A) class reserve for exploration is calculated at Group I deposit subjected to its detailed study area. Boundaries of reserve blocks shall be restricted to only excavation workings and exploration boreholes.

In the deposits under development, A class reserves are calculated from the data of mining exploration and preparing excavation works for mining operations. This includes reserves of prepared or ready-to-extract blocks that meet the exploration requirements of the classification in this category.

The measured (B) category reserve for exploration is calculated at Group I and Group II deposits. This includes reserves that have been allocated in detail areas or within other parts of graphite deposits that meet the requirements for estimating reserves by the objective class of the graphite ore body. The main parameters of the geological structure of the blocks and the assessment of the quality of the minerals, which are classified as objective class reserve, shall be determined by sufficient representative data.

The contour of the category B reserves should be determined for exploration by mainly exploring boreholes and excavating workings, and without extrapolation. If the ore bodies or parts of ore body are characterized by simple geological settings, stable thickness and even distribution of mineralization, their reserve can be delineated into measured (B) class, on the basis of well defined geophysical and geochemical survey results, contouring with limited extrapolation lines.

The spatial location of graphite ore body or its part should be studied to a degree that allows for the possibility of delineation options that do not significantly affect the understanding of the conditions of ore occurrence and the structure of the deposit (area). The selected industrial (technological) types of graphite ores, as well as internal substandard areas, should be contoured; if it is impossible to delineate, statistical determination of their ratios is allowed.

In the deposit under development, the class B reserves are calculated from data resulted by additional exploration, operational exploration and preparing mining operations in accordance with the requirements of the reserve classification.

The indicated (C) class reserve for exploration is calculated on deposit or its part (area) within which the grid density of exploration adopted for this reserve class is maintained, and the reliability of the information obtained is confirmed by the results obtained by exploration at the detail areas, or data obtained during operational exploration or operational procedures from mine site under exploitation.

The contours of a category C reserve are generally determined by exploration workings, and for large deposits or ore bodies with stable geological settings, by limited extrapolation that based on geological setting, taking into account changes in morphostructure, thickness of ore bodies and ore quality.

On Group 3 deposits, the requirement for category C reserves is the presence of mining operations that track graphite ore deposits along with their strike and dipping directions. Within the contour of class C reserves, it can be used statistical assessment to differentiate the industrial (technological) ore types and internal substandard parts and gangue minerals.

Inferred (P_1) category resource is evaluated for the deposit under exploration on a marginal area and deep located parts in adjacent to the reserve estimated area in C-classification; and for the area under prospecting-evaliating works in few excavation workings and boreholes. The boundaries of the area being assessed for the determined (P_1) resources will be determined by extrapolation based on the results of the study of changes in the thickness and content of the ore body, the regularity in chages of accumulation and location of the graphite deposits, and geophysical and geochemical data.

6.4. Based on the geological reserves of the deposit, it will be developed a Feasibility Study for the mining of the deposit. According to the Feasibility Study, substandard ores, mining losses and contaminants are excluded from the geological reserves within the boundaries of the future mine, and the remaining part is classified as Proved (A ') and probable (B') reserves. Classification and instruction of resources and deposit reserves in accordance to requirements that demonstrated in “Methodological Recommendation for applying of the Classification of Deposit Reserves and Mineral Resources of certain solid minerals”.

Proved (A’) mineable reserve is based on the geological reserves of mineral resources of Proved (A) and Probable (B) categories; and on background of pilot test results selecting mining technics and technology, relevant assessments and ore technology features; and defined in details the engineering solutions, environmental and occupational safety taking in account hygiene, rights, human resources, management organizational structure, supply infrastructure, social and economic services, and economic efficiency calculations and related factors in accordance to "Feasibility study for deposit exploitation of mineral resources".

Probable (B') mineable reserve is based on geological reserves of mineral resources of Measured (B) and Indicated (C) categories; and on background of pilot test results selecting mining technics and technology, relevant assessments and ore technology features; and defined in details the engineering solutions, environmental and occupational safety taking in account hygiene, rights, human resources, management organizational structure, supply infrastructure, social and economic services, and economic efficiency calculations and related factors in accordance to "Feasibility study for deposit exploitation of mineral resources".

6.5. Reserves are calculated separately by classification, mode of operation (open pits, adit horizons, mines etc.), industrial (technological) types and sorts of ores (oxidized ore, weathered graphite ore and primary graphite ore), and their economic value (balance ore, off balance ore). (per cent) labelling of graphite is determined. The ratio of different industrial types and types of ores, if it is not possible to delineate them, is determined statistically.

In addition to determining the percentage of composition of graphite ore brands that estimated within the reserve; and statistical assessment will be made of the quantitative ratio of ore technology types and brands, if it is not possible to distinguish the boundaries of the varieties.

The ore reserves are estimated without moisture (on dry basis) indicating moisture in ore of dry basis. For water-bearing porous ores, it should be calculated the graphite ore reserves on dry basis, too.

6.6. At the deposits under mining operation, the graphite ore reserves that stripped, prepared and ready for excavation, as well as those located in the shaft pillars of mining and mining preparatory workings, are calculated separately with a division by reserve classification in accordance with the degree of their study.

6.7. Reserves of graphite ores enclosed in protected areas of large water reservoirs and streams, settlements, buildings and agricultural facilities, nature reservatums and monuments, historical and cultural sites, forest reserves and part of the river basin under special protection should be estimated in accordance to referring reserve classification and turning tthem to non-productive reserves (off-balance reserves).

6.8. For the deposits under operation, in order to control the completeness of the development of previously approved reserves and substantiate the reliability of the calculated new reserves, it is necessary to compare the exploration and operation data on reserves, conditions of occurrence, morphology, capacity, internal structure of graphite deposits, and the content of useful components. In the absence of such kind of guidelines, the same qualitative recommendations can be followed such as the Russian "Methodological Recommendations for the Comparison of Data on Exploration and Development of Solid Mineral Resources, 2007".

The data comparison of results between exploration works and operational activities that conducted to the deposit should contain the contours of bodies previously approved by Minerals Professional Council of Mongolia (MPCM) and obsolete reserves (including those extinguished and remained in protecting shaft pillars), written off as unsubstantiated reserves and the contours of areas of incremental reserves, and it should demonstrate the volume of reserves (by category, ore bodies and deposit as a whole) showing reserve balance tables on the movement of reserves (by a quarterly and annual basis). Furthermore, the compaing data should contain a balance sheet of the ore with a characteristic of its quality in the contour of extinguished reserves, losses during extraction and transportation, the yield of goods and losses during the processing of ores. The results of the comparison are accompanied by graphs illustrating a change in the image of the mining-technical and geological conditions of the deposit.

If the exploration data are generally confirmed by the exploitation or the minor discrepancies do not affect the technical and economic performance of the mining enterprise, the results of geological and mining surveyor measuring data can be used to compare the exploration and exploitation data.

When analysing the results of the comparison, the values of the changes in estimated parameters of the operationl exploration or exploitation data should be determined (distribution areas and thickness of ore body, content of useful components, volume weight, regularity of their changes etc.), ore reserves and quality, and the reasons for these changes.

For a deposit, where, in the joint conclusion of the subsoil user and mining inspection organization considering the reserves or quality of the ores approved by Minerals Professional Council of Mongolia have not been confirmed at the time of mine development or adjustment factors needed into previously approved parameters or reserves, it is possible to calculate and use the correction factor for unsubstantiated reserves.

6.9. In recent years, the geo-statistical modelling method (proposed by J.Materon) has been widely used in the calculation dedining regularity of spatial distribution and data variety evaluation of any key parameters such as useful mineral content, crossing thickness, metro-percent of the ore bodies in deposits.

The efficiency of the application of the geostatistical method is largely depening on quantity and quality of the initial exploration data, the methodology for the analysis of the primary data and the modelling corresponding to the individual geology of the structure of the explored field (distribution laws of calculating parameters, nature of trend and anisotropy, influence of deposit structural boundaries on structural and qualitative evaluation of experimental variograms and determination of parameters of search ellipsoids, etc.).

The number and density of exploration crossings (grid) or initial sampling number should be sufficient to justify optimal interpolation formulae (krieging procedure, inverse distance weighting, nearest-neighbor interpolation to determination of reliable data (for two-dimensional modelling- at least a few dozen data of prospecting crossings, for three-dimensional - at least the couple hundred sampling data) for subdivision of reserve contour space into sub-blocks with reliable data (eg. Grade of useful mineral resources etc.). And it is recommended to study the properties of spatial variables correlating to basic parameters of the deposit and ore bodies in the areas of detail.

When constructing a geo-statistical block model of the deposit, the maximum possible size of the sub-block (elementary block) is chosen on the basis of the planned mining technology, the minimum size being determined by the density of the exploration grid established on the deposit. It is not recommended to take the size of the sides of a sub-block less than 1/4 to 1/8 of an average density grid).

In order to comply with this requirement, if the sub block (elementary block) size is enlarged, it is possible to use a method that takes into account the volume factor of the primary (parent) and sub-elementary blocks to determine the ore volume.

The results of the reserve estimation by Geostatic method can be presented in two types: the calculation of the grid of the same equilateral blocks produces calculation tables for all elementary (sub) blocks together with the determined values of the main parameters; and when calculating large geological blocks of individual geometry, each block must be bound in space and have a list of samples in the zone of influence.

All digital data sets (sampling data, coordinates of samples or ore crossings, rock information, analytical expressions of structural variograms, etc.) should be provided in formats accessible for users and expertise using the most common software packages (for example, as DBF files with a separate way of encoding missing values or as ASCII files of standard GEOEAS format). Models of symmetrical (or theoretical) transformations, trends and variograms, other parameters are presented in analytical and descriptive forms.

The geostatistical way of calculating reserves is considered to be the best way to establish estimates of the average content of the utility component in blocks, ore bodies and the deposit as a whole, allowing to reduce the delineation errors of ore bodies with a very complex morphology and internal structure and optimizing the mining technology. However, geostatistical methods of reserve estimation should be controlled in their application and subject to the geological features of the deposit. The results of geo-statistical modelling and estimation should be verified and concluded by comparison with the results of traditional methods of reserve estimation at representative sites/areas, which have been studied in details.

6.10. During the computer calculation of reserves, it shall be possible to view, verify and correct the raw data base (coordinates of exploration workings and boreholes, data of inclinometry, contact marks, results of sampling, etc.), the results of intermediate calculations and compilations (Catalogue of ore crossings that identified according to ore standards/conditions; geological sections or maps with contours of industrial standard mineralization; projection of occurrences to horizontal or vertical planes; catalogue of calculation parameters by blocks, benches and pit sectiions) and summary results of reserve estimations. Output documents and computer graphics shall meet the existing requirements for these documents in terms of composition, structure, form, etc.

6.11. The reserves estimation of accompanying minerals and components is carried out in accordance with Methodological recommendations and use on complex reserve estimation of mineral resources. If this type of recommendation has not been yet developed, a similar recommendation can be followed, i.e. the Russian “Recommendation on the Complex Study of Deposits and Reserve Estimation of Accompanied Minerals and Components, 2007”.

6.12. Reserves are calculated in accordance with the Methodological Recommendations on Composition and Design Rules of Materials Submitted for State Expertise on Inventory of Metallic and Non-metallic Minerals."approved by the Russian Ministry of Foreign Affairs in accordance with the established procedure.

The report of exploration work results with reserve estimation should be prepared in accordance with the relevant instructions prepared by the Minerals Professional Council of Mongolia, and a copy of the report should be handed over to Authorized Central Archive of Geology and Mining with the relevant completed documents in accordance with the established procedure.

Seven. Study degree of deposit

7.2. In the case of an assessed graphite deposit, it is necessary to determine the overall size of the deposit and the quality of the mineral, and the most promising sites of deposit have to be identified to support the exploration sequence and subsequent development.

The parameters of standard/condition for reserve estimations and resource assessments will be determined based on feasibility studies that calculated from the results of prospecting-evaluating work on the whole deposit or its well-represented area, as well as by comparing condition parameters with deposit data of similar geological formations and mining and economic conditions.

In the detailed study of the assessed deposit, the mass of mineral is estimated at a indicated (C) classification and the rest of them is assessed as inffered resource (P_1).

Considerations of the methods and systems of exploitation of the deposit and the possible scale of production are justified on the basis of analogue mine projects; and enrichment technology schemes taking into account the complex use of raw materials including accompanying minerals, the possible yield and quality of the products are determined on the basis of laboratory-technological studies on samples; and capital costs for the mine development (mine construction), the cost of the products and other economic indicators are determined on the basis of aggregated calculations correlated to analogue mine-projects.

Issues of household-drinking and industrial water supply for future mining enterprises are evaluated on the basis of hydrogeological conditions, water point information, and hydrogeological surveys that conducted to the region for agricultural and other purposes.

The possible impacts of the exploration and future mining operation to the environment should be considered and evaluated.

7.3. In order to study in detail the morphology of ore body, material composition of ores and the development of technological schemes for the enrichment and processing of ores, pilot-industrial development (PID) can be carried out to the assessed deposit (sites/areas). The PID is carried out within the framework of the exploration phase project that prepared by mineral deposit explorers and mining operators and reviewed and approved by the relevant state mining authority of Mongolia. The PID project is conducted within the framework for less than 3 years on the most characteristic, representative sites of the majority of the deposit, including typical ores of the deposit.

PID project is usually dictated by the identification of geological features of deposits (morphology and internal structure variability), mining and geological conditions, mining and ore enrichment technologies (natural varieties and technological types of ores and their relationships). These issues can only be addressed if deposits are discovered to a significant depth and extent.

PID is appropriated for the development of large and very large deposits where the developed technological design is tested and refined in small enrichment factories before proceeding with the construction of the main factories.

7.4. In explored deposits, the quality and quantity of reserves, their technological properties, hydrogeological, mining and ecological conditions of exploitation should be studied and mining operations with sufficient sophistication for the development of engineering-economic justification of the decision in the manner and conditions of their involvement in industrial development, as borehole as on the design of the construction or reconstruction on the basis of them of the mining enterprise.

In terms of knowledge degree, explored deposits shall meet the following requirements:

- The possibility of qualification of reserves according to categories corresponding to the group of complexity of the geological structure of the deposit;
- The physical composition and technological types of industrial procedures and mineral grades have been studied in detail to provide basic data sufficient for the design with the complex extraction of all useful components, industrial waste management and identification of the utility direction of the waste formed or the optimal option for its storage or disposal;

- Study the use of industrial waste and its storage and protection;
- Study other minerals that can be used in addition to the main minerals (rock from stripped overburden, groundwater, etc.), investigating the minerals are contained in them, and to determine the quantities that can be used;
- Hydrogeological, engineering-geological (geotechnical), geocryological, mining-geological, ecological and other natural conditions have been studied in detail, providing input data, the necessary conditions for the development of the deposit, taking into account the requirements of the environmental protection legislation and the safety of mining operations;
- The data on the geological structure, conditions, morphology and location of deposits, the quality and quantity of reserves is confirmed in the detail areas representative of the entire deposit, the size and position of which are determined by the subsoil user on a case-by-case basis, depending on their geological characteristics;
- Consideration was given to the possible impact of the development of the deposit on the environment and recommendations were made to prevent or reduce the projected level of negative environmental effects; the calculation of the parameters of the condition is based on technical and economic calculations that make it possible to determine the size and industrial value of the deposit with the necessary degree of confidence.

The ratios of reserves between the various classes are determined by the subsoil user and experts of Mineral Professional Council taking into account acceptable business risk.

Based on the geological structure of the deposit, mining methods, system selection, and experience used in similar projects, the project implementers will determine the amount of (C) classification, resources that can be included in the Group I and II mining projects and make a decision based on the recommendations of the Mineral Professional Council.

A deposit is considered to be ready for mining after it has been explored and the mineral reserves have been discussed and registered by the Mineral Professional Council by complying with the above requirements.

Eight. Re-estimation and registration of deposit reserves

Recalculation and reallocation of reserves in accordance with the established procedure shall be initiated by the license holders State authorities and Occupational inspection authorities in case of a significant change in the quality and quantity of the deposit and its geological reserve, economic assessment resulting from additional exploration and mining activities.

At the initiative of the license holder, the reserves are recalculated and reapproved at the deposit under operation due to events that significantly degrade the enterprise’s economy:

- Substantial lack of confirmation of proven and previously approved graphite reserves and (or) quality of graphite decreasing more than 20%;
- Objective, substantial (more than 20%) and stable fall in the price of production while maintaining the production cost level;
- Changing the quality requirements of the mineral industry; and

- When the total quantity of balance reserves written off and intended to be written off as unsubstantiated (in the process of completing exploration, exploitation exploration and exploitation of the deposit) and also not subject to processing for technical-economic feasibility reasons, exceeding the existing mining decommissioning regulations (i.e. more than 20 per cent).

At the initiative of the control and oversight bodies, reserves are recalculated and re-declared in the event of instances that infringe on the rights of the subsoil mineral resource owner (State) to unreasonably reduce the taxable base:

- An increase of more than 30 per cent in balance reserves over those previously approved;
- A substantial and steady increase in the world prices of the enterprise's products (more than 30% of the prices included in the justification);
- The development and introduction of new technologies that significantly improve the economy of production;
- The identification of valuable components or harmful inmpurities in ores and host rocks that have not been previously taken into account in the assessment of the deposit and the design of the enterprise.

Economic problems of the enterprise caused by temporary causes (geological, technological, hydrogeological and mining-related complications, temporary fall of prices of products) will be solved through the use of a reference economic mechanism, and reserves are not need to be recalculated or re-registered.

Nine. References

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11.Regional metallogeny of Central Asia. VSEGEI Publishing House, St. Petersburg, 2012.

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13. “Instructions and requirements for conducting thematic and medium-, large scale hydrogeological mapping and hydrogeological survey on deposit during mineral exploration”. Order No. A / 237 of the Minister of Mining and Heavy Industry of Mongolia, dated December 12, 2017.

14. Solid minerals and rocks. Technological testing in the process of geological exploration. STO RosGeo 09-001-98, Moscow, 1998

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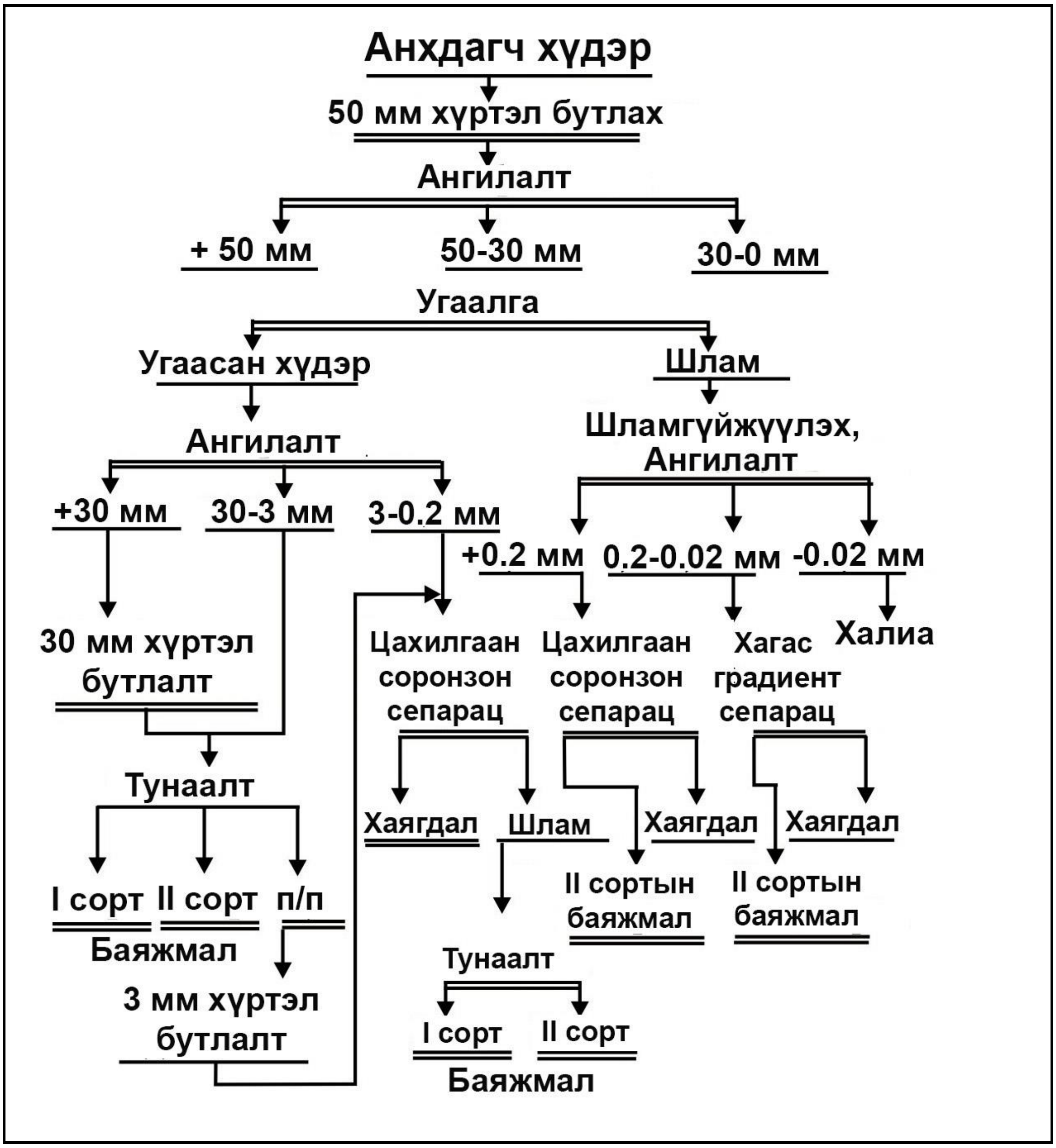
Ten. Appendix

Appendix 1



Scheme of manganese oxidized ore processing technology

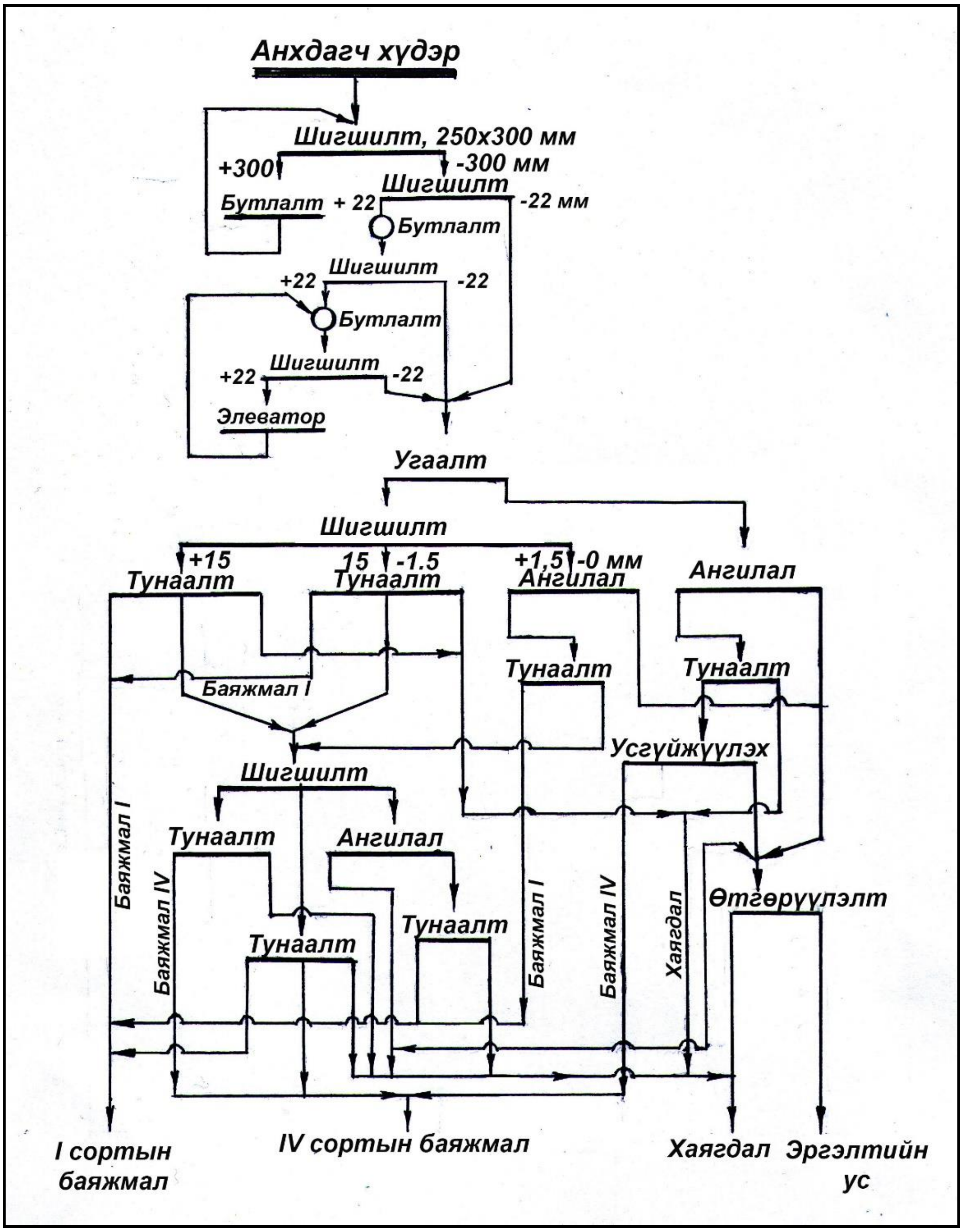
Nikopolsk deposit, Ukraine

Appendix 2

Scheme of manganese carbonate ore processing technology

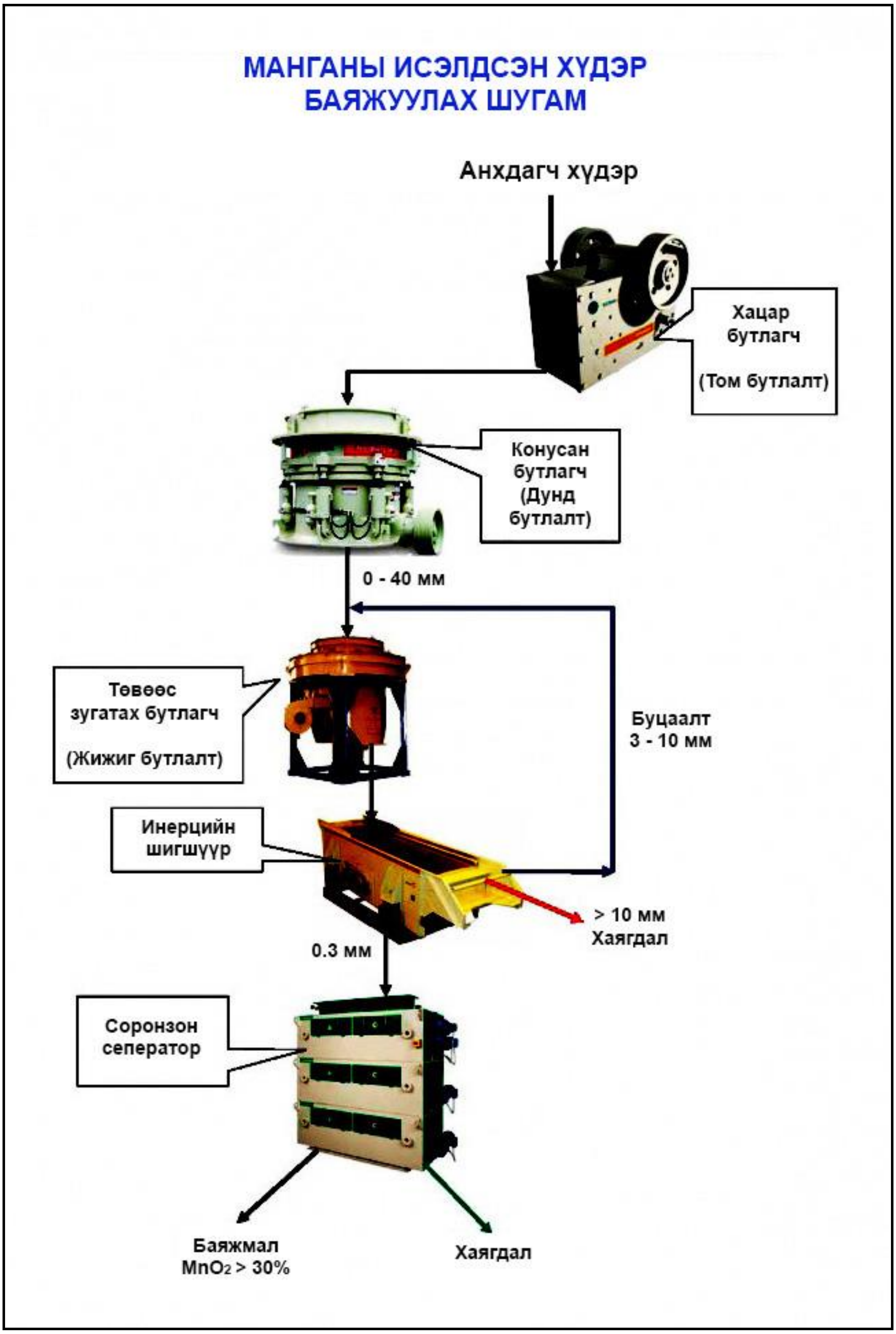
Nikopolsk deposit, Ukraine

Appendix 3

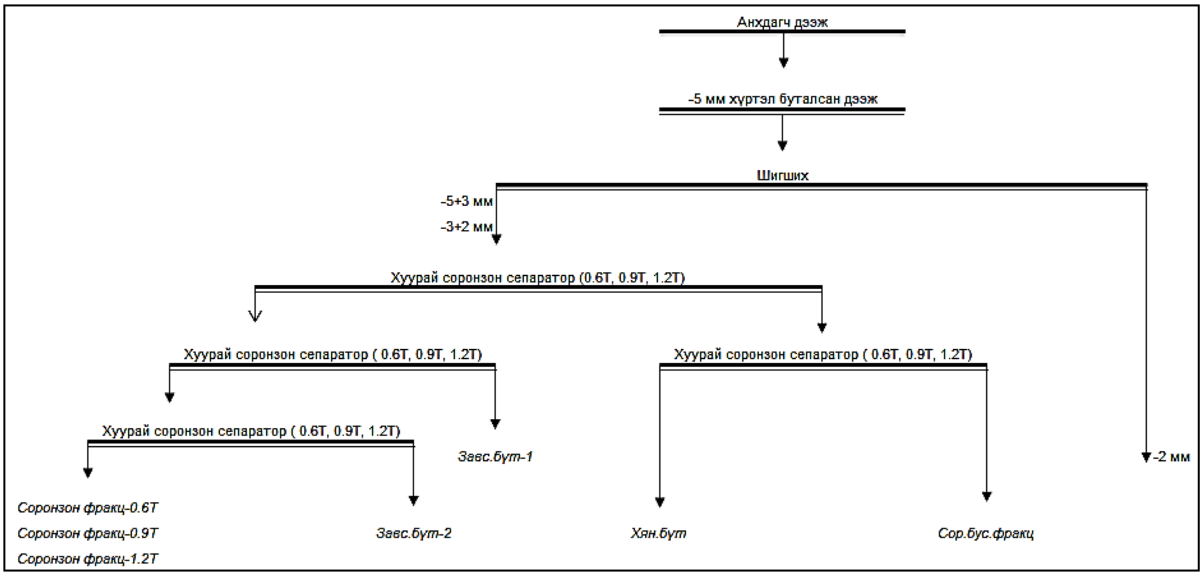


Scheme of manganese ore processing technology
Chiatursk deposit, Georgia

Appendix 4


МАНГАНЫ ИСЭЛДСЭН ХҮДЭР
БАЯЖУУЛАХ ШУГАМ
Анхдагч хүдэр
Хацар бутлагч
(Том бутлалт)
Конусан бутлагч (Дунд бутлалт)
0 - 40 мм
Төвөөс зугатах бутлагч
(Жижиг бутлалт)
Буцаалт 3 - 10 мм
Инерцийн шигшүүр
> 10 мм Хаягдал
0.3 мм
Соронзон сеперато р
Баяжмал MnO2 > 30%
Хаягдал

Appendix-5



Technology scheme Burged khar uul deposit, Mongolia

Appendix-6

Classification of manganese ore (IS:11895:2006) /India/

No	Type	Content (%)				
		Mn	Fe	SiO_2	MnO_2	Fe+Mn
1	Manganese ore	>35	-	-	-	-
2	Fe-Mn ore	35-25	23-13	-	-	>48
3	Si-Mn ore	30-25	-	>15	-	-
4	Mn-Fe	25-10	48-30		-	>55
5	Mn ore (Chemical composition)	-	<5	-	>78	-

Technical characteristics of manganese ore for iron and steel production (IS:11281:2005)

Production	Ore with steel melting grade (11-40 мм)	Blast furnace ore (25-85 мм)
Mn	>25%	>25%
Al_2O_3	<8%	-
SiO_2	<8%	
Fe_2O_3	18-24%	-
P	<0.18%	<0.35%