MINISTRY OF MINING
AND HEAVY INDUSTRY

Australian Aid

AMEP
Australia Mongolia Extractives Program

METHODICAL RECOMMENDATION

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

(GRAPHITE)

Ulaanbaatar

2021

Disclaimer

Australia Mongolia Extractives Program is supported by the Australian Government and implemented by Adam Smith International.

Adam Smith International

CONTENTS

1. Introduction 4

2. General concepts 5

3. Classification of deposits on the complexity of geological settings for exploration purposes 11

4. Studies of geological structure of deposits and ore composition 12

5. Studies of ore technological properties 28

6. Studies of hydrogeological, engineering-geological, geotechnical, geo-ecological and other natural conditions of deposits 34

7. Reserve estimation and resource assessment of deposits 38

8. Exploration status of deposit 44

9. Recalculation and re-approval of deposit reserves 47

10. References 49

11. Appendices 51

List of tables

Table 1: World market price of graphite and future forecast price (USD / ton) 7

Table 2: Information on density of exploration grids for exploration of graphite deposits 18

Table 3: Permissible marginal values of standard deviation to the carbon content of graphite 26

Table 4: Types, brands, and applications of graphite 31

Table 5: Additional parameters for graphite types and brands depending on the direction of application 32

Table 6: Statistical assessment of the complexity of the geological structure of the deposit and group correlation 52

The recommendation is developed by the School of Geology & Mining, Mongolian University of Science and Technology on the order of the Ministry of Mining and Heavy Industry of Mongolia, with support of the Australian-Mongolian Extractives Program (AMEP) implemented by the Australian Government (Adam Smith International).

The recommendation is approved by the Decree No. XX-202X of the Mineral Resources Professional Council on date of 3 June 2021, approved by the Minister of Mining and Heavy Industry by the order no.... .

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

GRAPHITE

Authors:

Ukhnaa.G (PhD)	Consultant geologist, professor, School of Geology and Mining Engineering, MUST
Enkhtur.D	Professional geologist of Mongolia

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.

This recommendation has been funded by the Australian Government through the Department of Foreign Affairs and Trade. The views expressed in this publication are the author's alone and are not necessarily the views of the Australian Government.

Introduction

This recommendation is based on “State Policy on Mineral Resources”, Article 16 of the “Minerals Law of Mongolia”, “Action Plan of the Government of Mongolia for 2020-2024”, and “Regulations on mineral prospecting and exploration activities” submitted by Order No. A / 20 of Minister of Mining and Heavy Industry on February 5, 2018, and “Classification and instructions for mineral resources and deposit reserves may be adapted based on the specifics of the type of mineral” approved by Order No. 203 of the Minister of Mining on September 11, 2015, and on the relevant provisions of the law, orders, procedures and instructions.

This methodological guideline contains recommendations on the application of the geological resources and reserves classification of solid mineral deposits to graphite deposits.

It will also provide practical assistance to exploration and mining license holders (entities), geologists and miners in conducting exploration of graphite deposits, preparing reserve estimations, registering them in the Unified Register of Mineral Resources, and conducting resource movements.

One. Basic terms

1.1. Graphite, its use and importance

1.1.1. The word “graphite” is derived from the Greek word “to write”. It is a crystalline form of the element carbon with its atoms arranged in a hexagonal structure. Its symmetry of crystal system’s formula is L66L27PC. It forms tabular crystals with a space of 0.141 nm between carbon atoms and 0.335 nm between the sheets. The crystalline structure of graphite determines its industrial and technical applications. The color of graphite is from steel gray to black, the gloss - metallic, sometimes - matt, hardness (Mohs scale) 1-2, density 2,1-2,2 g/cm^3, melting point - 3845±50ºC, therefore it is considered as a high-grade infusible material. The flammability of graphite is determined by the fact that 3% of it burns at a certain temperature. This value is 720-730°C for flaky graphite, 695°C for dense crystalline graphite, 510-550°C for hidden crystalline graphite, and 670°C for anthracite-derived graphite. Graphite in grids is opaque, only its plates less than 2 µm thick are thinly illuminated.

Graphite is chemically inert and does not dissolve in acids, but it is soluble in acids only under oxidizing conditions. When molten metals react to the graphite, carbides dissolve it therein. It has good thermal conductivity, but less thermal capacity.

Its electroconductivity is comparable to most metals, but coarse-grained graphite has electrical resistivity ranging from 9×10^{-4} to 5×10^{-5} Ohm·cm, and fine-grained graphite – from 8×10^{-4} to 2×10^{-5} Ohm·cm.

The graphite is greasily characterized to the touch, and characterized by low friction coefficient, due to the tabular structure of its micro-breaks and low hardness. It has high lubricating and intimate abilities.

1.1.2. Natural graphites are divided into distinct crystalline (average size of crystals greater than 1 µm) and crypto crystal (amorphous). Amorphous graphite crystals are not always visible even under a microscope.

Explicit crystalline graphite is represented by dense and scaly types. The dense ones are made up of closely connected crystals. Among the dense graphite is composed of large crystalline (the average size of the crystals is more than 50 µm) and fine crystalline. The small scaly graphite is the most expensive, and such graphite is used to produce high-value, flexible powders. Scaly differences consist of individual crystals or their parallel scaffolds that are shaped like scales. They are distributed within the Murzinsko-Kyshtym Ore Area in the Middle Urals, Minor Hingan Mountain in the Amur Region, Russian Federation, and in the Ukrainian crystalline shield (and in Mongolia?).

Crypto crystal (amorphous) graphite is represented by dense differences, stacked in the smallest, usually differentially oriented graphite crystals, and dispersed types in which such crystals are distributed in the host rock. Industrial values are only dense differences, especially with crystalline scales oriented in the same direction, which gives them plasticity and «greasy touch».

1.1.3. More than 50 percent of graphite is used in machinery, about 30 percent in chemical technology, and the rest in other industries. Graphite is used in many industrial sectors manufacturing of refractory materials, paints, lubricants, alkaline and solar batteries, electrically conductive paints and rubbers, pencils, machinery brake pads, engine crankshafts, nuclear reactors, aerospace technics and synthetic diamond produces.

Recent scientific and technological advances in nanotechnology have provided an important incentive to increase the use of graphite; i.e. the single-layer carbon nanotube was discovered in 1993. The nanotube that made of pure carbon, has a higher electrical conductivity than silver and copper, and it is equivalent to silicon in terms of semi- conductivity; and it can withstand temperatures up to 1500°C, is very light and 25 times stronger than high-quality steel and due to its durability and quality, it has been applied in many industrial sectors like as electronics and etc.

In recent years, graphite has become the main raw material for lithium-ion batteries in environmentally friendly electric vehicles, and its use and price have been growing rapidly. For example, a smartphone battery contains 15 g of graphite, a Chevrolet Volt car contains 30 kg, a Nissan leaf car - about 60 kg, and a Tesla Roadstar car - more than 100 kg.

The use of single-layered carbon nanotubes in the production of lithium-ion battery anodes has replaced lithium, cobalt, and nickel, which are likely to be depleted. In the future, scientists believe that graphite could become a raw material for energy to replace oil, if it is used at the moment only in a battery on the base of graphite, which are recharged in very short time, and very long-lasting; and this kind of battery will be used primarily in automobiles and soon in aircraft.

210-megawatt nuclear power plant composing of Pebble Bed reactors, which has been piloted in China, also uses graphite in range ~3,000 tons for the start and 1,000 tons per year are needed to maintain 1 MW power craft unit, in further.

In connection with this, there are implementing a project to produce 260,000 tons of lithium-ion battery anodes in China and to build a plant with a capacity of 100,000 tons per year in Japan. Due to the use of graphite in the production of lithium-ion batteries, the current price of 1 ton of graphite has increased from 7,000 to 20,000 USD, but the use of graphite in batteries makes the price of battery three times cheaper than using cobalt, therefore the graphite is still increased in use.

Global graphite consumption was estimated at U$ 14.3 billion in 2019, an average annual price increased at 5.6%, and is predicted to reach U$ 22 billion by 2027. Global consumption of natural graphite increased from 600,000 tons in 2000 to 1.1 million tons in 2011. As of 2013, the world's graphite reserves were estimated at 71 billion tons.

Graphite production is increasing by about 400 thousand tons per year. Today, the demand for graphite has been growing at an annual rate of 5% since 2000, which has pushed up the price of the mineral and increased investment in the sector.

For the last 10 years, the Institute of Far Eastern Geology, Russian Federation has been revealing significant accumulation of gold and platinum (average grade is 3.7 g/t or PPM) in some graphite deposits, and has developed technology to extract these elements, considering great importance to the exploration of gold deposits in black schists.

In the world market, the price of graphite is determined by the main factors such as the carbon content and particle size of graphite.

World market price of graphite and future forecast price

Table 1

Years	The price of 1 ton of product, in USD		
	Coarse-grained, mesh -50 to +80	Medium-grained, mesh -50 to +80	Fine-grained, mesh -100
2017	1370	849	802
2018	1419	939	837
2019	1437	968	824
2020	1420	928	818
2021	1440	961	826
2022	1472	921	837
2023	1475	923	817
2024	1519	907	813
2025	1549	964	815
2026	1581	926	822
2027	1660	985	837
2028	1607	978	823
Дундаж	1495.75	970.75	802.58
2017	1370	849	802

Source: www.indmin.co, * mesh-US unit of measurement (-80 mesh = 0.117 mm)

1.1.4. One of the main factors affecting the quality of graphite is its impurities, of which grade varies depending on the industry in which it is used. For example, impurities of graphite used in the manufacture of refractory materials and chemical utensils include mica, calcite and sulfides; in graphite used in the manufacture of batteries - Cu, Fe, Ni and other metal compounds; in graphite used in the production of pigments – sulfides; in graphite used in lubricants - quartz, fieldspar and sulfide; and for the carbon brushes or conductors -abrasive mixtures, copper and other metals. If there is quartz, fluorspar, sulfide, the carbon brush or conductors are abrasive mixtures, copper and other metals.

1.2. The following genetic types of graphite deposits are distinguished: metamorphic, pneumatolite-hydrothermal, contact-metasomatic, pegmatite and magmatic origins. Metamorphic deposits are the most important.

1.2.1. The metamorphic graphite deposits are formed as a result of a deep regional metamorphism of sediments originally containing a diffuse organic matter, or as a result of the metamorphism of hard coal.

Metamorphic deposits formed as a result of the transformation of a diffuse organic matter are composed mainly of ores of crystalline graphite. The content of graphite carbon varies from 2% to 30%, occasionally reaching 60%. The deposits of graphite ores are represented by stratified bodies and lenses, reaching a considerable length ranging from couple hundred meters to 1 to 2 km, and their thickness reaches ranging from couple meters to first hundred meters. Graphite seams of deposits are associated with ancient metamorphic folded stratas/horizons of crystalline shales, gneisses, marbled limestone and dolomites, sometimes quartzites. This type includes the Soyuz and Tamginsk deposits in Priamurian Region, Taigin and Murzin deposits in the Middle Urals, Russian Federation, and the Zavalliev, Petrovsky, Starokrym deposits in Ukrainian Crystalline Massif; and Khargana River, Toirom, Serven, and Khar Chuluut deposits in Mongolia.

The deposits created by the ***metamorphism of coals*** are composed of predominantly crypto (amorphous) graphite ore; sometimes in subordinate quantities (20-40%) there is a clear crystalline graphite. Graphite ores form strata, seam-like bodies and large lenses of up to 30 m thickness lying among metamorphized rocks. In this kind of deposit, the graphite ores are often gradually replaced by anthracite or natural coke deposits. In graphite ore, there are observed sometimes plant prints. This genetic type of deposit has a high carbon content, which often reaches 60 to 80%, sometimes as high as 97%. The persistent impurities are calcite, quartz, apatite, and a small amount of sulphides.

This type of deposit includes: Noginsky and Kurei deposits in Krasnoyarsk Region, Russia, and in abroad - deposits of Mexico and South Korea.

1.2.2. ***Pneumatic and hydrothermal deposits*** are found mainly among gneiss. Graphite bodies were formed filling the cavities with graphite and other minerals had been crystallized from the high-temperature hydrothermal fluids rich in volatile compounds that circulated along these cracks due to gradual decrease of pressure and temperature. There are mostly dense-crystallized differences in graphite. It is accompanied by pyrite, titanomagnetite, quartz, biotite, orthoclase, augite, apatite, rutile, calcite and other minerals. The content of these impurities usually does not exceed 50%.

The ore bodies are represented mainly by conformal layers (plastic) to the host-rock and sometimes by veins splitting the host-rock. Large graphite bodies of industrial importance are rare; Sri Lanka's largest deposits are the most well-known.

1.2.3. ***Contact metasomatic deposits*** are associated with the contact of minor intrusive bodies and extensive carbonate rocks. At contacts of carbonate rocks, graphite (mostly explicit crystalline scale) occurs as an irregular form of deposit, vein and stock-like bodies, and is scattered in host rocks. The content of graphite carbon is usually 5 to 20%. Deposits of this type have rare distribution, and are small and predominantly developed in eastern Canada. This genetic type includes the Tas-Kazgan Deposit in Uzbekistan.

1.2.4. ***In pegmatites***, industrial concentrations of graphite are rarely observed, usually as small scales- and radial-shaped aggregates. Most often graphite develops in vein wall, (vein selvage), occasionally - in central parts of the pegmatitic bodies. Small deposits of this genetic type are known in Canada, the United States and Italy.

1.2.5. Actually, ***magmatic deposits*** of graphite are associated with intrusive and effusive rocks of different composition - from acidic and alkali to mafic. The carbon source may be the gaseous compounds of the parent magma, as well as the rock assimilated by the magma (carbonate or organic residues). Graphite bodies of this type deposits are in the form of irregular stocks, nests and veins. Actually, magmatic graphite deposits are characterized by small reserves and high quality of raw materials (30-40% of graphite carbon). An example is the Botogol Deposit in the Eastern Sayan Region, Russian Federation, where graphite is represented by a dense-crystalline difference.

1.3. In accordance to proposal of researcher I.F.Romanovich (1986), the types of graphite deposit formations were classified into the following types of formations.

1.3.1. Ore formation with rich content of graphite with full crystalline and scaly structures. Deposits of this type of ore formation are located in alkaline intrusive rocks, forming stock-like bodies, lenses, veins, and nest-shaped bodies within alkaline intrusive bodies, or along with contacts of gabbro and granite bodies, and rarely in gneiss. Therefore, the mineralization of this formation can be attributed to magmatic, boundary metasomatose and pneumatolithic-hydrothermal types. The thickness of vein bodies takes tens of centimeters to several meters, while the stock-like and nest-like bodies -several meters to several tens of meters in diameter. The carbon content of bodies that belonged to the formation varies in wide range. There are inlaid ores with very rich content (carbon content is 60 to 98%), medium grade graphite dissemination in silica rocks (carbon - 15 to 60%) and poor ore composing graphite inclusions in siliceous rocks (carbon – 5 to 15%).

This type of graphite ore formation, which are the main representatives of the world's richest graphite deposits. is represented by Bogala Deposit in Sri Lanka, Botogol in Russia, Tas-Kazgan in Uzbekistan, Te-Ma in North Korea, Dollon in the United States, and some deposits in India and Canada.

1.3.2. Graphite inclosure ore formation deposits in gneiss and other metamorphic rocks. The deposits of this formation are usually found in rocks had been metamorphosed up to granulite and amphibolite facies levels due to regional metamorphism and are the most common type of graphite. Graphite ore bodies are layered and lenticular-shaped, with thicknesses ranging from a few meters to tens of meters, and length ore bodies from a few hundred meters to kilometers along with its strike. The graphite content of the ore body varies from 2.5 to 20%.

The ore is composed of quartz, mica, feldspar, chlorite, sillimanite, pyroxene, calcite, apatite, garnet, pyrite and other minerals. Carbonates are considered as harmful impurities with sulfides as they aggravate the conditions of ore enrichment. Graphite inclusion ore consists of agglomerates of scaly graphite ranging in size from 0.1×n mm to several millimeters. This type of graphite deposits is widespread in Russia, India, Sri Lanka, Austria, the Czech Republic, China and Mongolia.

1.3.3. Graphite rich ore formation derived from apo-hard coal (altered coal). Graphite-rich ores formed as a result of coal seam metamorphism form seams and lenses. Thickness of the ore body varies from tens of centimeters to about ten meters. The ore has layered, foliated, brecciated, and rarely porous texture. The ore is composed of a mixture of cryptocrystalline and scaly-crystalline types of graphite. Crypto-crystals have a particle size of 1 to 100 μm.

About 35% of the ore mass is made up of scaly-shaped crystalline graphite. Gangue minerals are composed of fine-grained nest-like agglomerations of calcite, chalcedony, and zeolite. Pyrite inclusions also are contained in oxidized ores up to 0.1% and in primary ores up to 1.3%. Ores are classified as graphite-rich ores (50-90% graphite) and poor ores (20-40% graphite). Graphite deposits of this formation have a large base for reserves and mining and are distributed in North Korea, Mexico, Russia and China.

1.3.4. Graphite formation hosted in weathered gneiss. Basically, it belongs to formations of graphite that contained in crystalline shale and gneiss, but the weathered ore looks very different from the non-weathered ore, so it is classified as an independent structural-formation unit. Ore accumulations can be layered or lenticular, but they are more complex due to field and linear weathering. The mineralization of this type of deposit can be seen in the example of the Zavalyev deposit in Ukraine, for example, the upper strata are rich in clay minerals such as hydromica, montmorillonite, nontronite, kaolin, and hydrochloride, taking the ore content ~10% graphite, 25% quartz, 50% clay minerals, 10% ferruginous hydroxide, and 10% garnet and feldspar. The density of the ore is 1.7 to 2.52 g / cm^3. Silicified and carbonated graphite ores occur in this zone. The middle zone consists of semi-powdered graphite ore with a density ranging 1.86 to 2.64 g / cm^3, containing 10% graphite, 30-40% quartz, 10-25% feldspar, 10-40% clay minerals, 10-15% mica, 10% garnet, sillimanite and apatite. The lowermost zone consists of dense graphite ore, so its density is 2.42 to 2.98 g / cm^3. It contains 6-8% graphite, 30-40% quartz, 20-30% feldspar, 25-30% biotite and other mica, and 10% garnet, sillimanite, apatite and pyrite. Therefore, the weathering process adversely affects the quality of graphite, and the middle and lower layers of the deposit contain ore of industrial significance.

Two. Grouping deposits' complexity of geologic settings for exploration purposes

In terms of size and shape of ore bodies, their capacity variability, internal structure and graphite distribution, the graphite deposits (areas) of the graphite ores are corresponded to following three groups (Groups 1, 2 and 3), in accordance with the "Classification and instructions for mineral resources and deposit reserves may be adapted based on the specifics of the type of mineral" approved by Order No. 203 of the Minister of Mining on September 11, 2015. These include:

3.1. **The 1st group** consists of mainly metamorphic deposits (and/or areas) of simple geological structure with ore bodies represented by deposits of seams and seam-like bodies with relatively sustained thickness, even distribution of graphite carbon, undisturbed or slightly disturbed deposit. The main representatives of Group I deposits are Taigin deposit, Noginsk mine and mined areas, parts of Murzinsky deposit, Russia and Suuj Uul, Khar Chuluut and Zulegt deposits, Mongolia.

3.2. **The 2nd group** consists of mainly metamorphic deposits (areas) of graphite in a complex geological structure with ore bodies represented by seams and lenses with a relatively sustained thickness, uniform or uneven distribution of graphite carbon and disturbed deposits; The main representatives of Group II deposits are Zaval'skoye deposit, Ukraina; Noginskoye, Kureyskoye, Bezymyannoe (Nameless) deposits, Russia; and Toirom, Serven, Goojinkhoi Uul and Khar Chuluut deposits, Mongolia.

3.3. **The 3rd group** consists of contact-metasomatic, magmatic, rarely metamorphic graphite deposits (areas) with ore bodies of very complex geological structure represented by minor beds, lenses, stocks and nest-like bodies with unstable thickness and uneven distribution of graphite carbon. The main representatives of Group III deposits are Petrovskoye, Soyuznoye, Troitskoye and Botogol deposits, Russia; Tas-Kazgan and Zhdanovskoye deposits, Uzbekistan; and Khargana river and Itgel-Naidvar deposits, Mongolia.

3.4. The identification of a deposit (area) into a group is determined by the degree of complexity of the geological structure of the main bodies of the mineral resource, comprising at least 70% of the total reserves of the deposit (area).

3.5. When a deposit (area) is classified into certain complexity group, it can be taken in account the proposed scenario (Appendix 1) for the Russian resource/reserve classification, which quantifies the mineralization status of the deposit.

Three. Geologic settings of deposit and studies of ore Mineral composition

4.1. For an exploration field/deposit, it is necessary to have a topographic base whose scale is appropriate to its size, geological features and topography. Topographic maps and plans for graphite deposits are usually produced at scale 1:1000 to 1:10 000.

All exploration and operational workings (trenches, dug pits, main trenches, adits/galleries, mines/shafts), detailed geophysical observation profiles, boreholes (rotary drilling, reverse circulation drilling, etc.), stations of geophysical measurements, geochemical sampling points and profiles, and all types of natural outcrops are tied by geodetic measurements and surveyed on a topographic base map. Using data of underground mining surveyor, the sites of underground excavation and underground boreholes are plotted to the Mining Horizon Maps. They are usually plotted at scale 1:200 to 1:500, and unified underground surveyor maps - 1:1,000, 1:2,000 and 1:5,000 depending on the size of the deposit, geological formation and survey accuracy. For boreholes, the coordinates of the points of intersection between the roof and the base of the ore body must be calculated and the extensions of their barrels/hollow space will be plotted on the horizon plane of maps and sections.

4.2. The geological structure of the deposit should be studied in detail and plotted on a geological map at scales 1:1000 to 1:10,000 (depending on the size and complexity of the deposit), geological sections, plan maps, projections and, where appropriate, block diagrams (in 3D) and models.

The geological and geophysical materials of the deposit should give an idea of the size and shape of the graphite deposits, the conditions of their occurrence, their internal structure and continuity, the degree of facies variability, the relief features of the roof belonging to productive ore bodies, placement of various types of graphite ores, the characters of pinch out of ore bodies, the characteristics of the change of the host rocks and the correlation of ore bodies to the host rocks, the folded structures and the tectonic faults in necessary and sufficient level of studies to be correlated the graphite bodies and become justified for the reserve estimation. In the case of complex deposits of productive bodies, it is advisable compiling the contour-line maps for roof and base of certain ore accumulations.

Based upon exploration criteria, it has to be determined the geological boundaries of the deposit or mineralized area, within which should be evaluated the predictive resources of category P_1.

4.3. Outcrops and near-surface parts of graphite ore deposits should be studied by excavation works (trenches, main trenches, dug pits, cleanups) and shallow bore holes using geophysical and geochemical techniques and sampled in detail, which makes it possible to establish the morphology and conditions of the ore bodies, the depth of development and the structure of the weathering zone, the degree of weathering of the ores and the characteristics of the change in the substance composition, the technological properties and content of graphite and conducting reserve estimation for weathered and mixed ores separately by industrial (technological) ore types.

4.4. The exploration of graphite deposits for depth is carried out mainly by drilling method, with the subordinate role of mining operations using geophysical research methods such as surficial and down hole logging methods, and excavation works accompanying with geochemical sampling procedures from the bore holes and excavations.

The exploration method including the ratio of excavation works to drilling, types of mining operations and drilling methods, geometry and density of the exploration density, methods and way of sampling - should make it possible to calculate reserves on the explored deposit by categories, corresponding complexity group of its geological structure. It is determined on the basis of the geological features of graphite deposits, taking into account the possibilities of mining, drilling and geophysical means of exploration, as well as the experience of exploration and exploitation of similar types of deposits. The need for mining operations, the choice of types and the scope of work shall be determined on a case-by-case basis, considering the geological features of the deposit the possibilities of geophysical data of exploration, and experience in the exploration and exploitation of similar deposits.

Optimum exploration options should take into account the spatial distribution of graphite, the texture-structural features of graphite deposits, and the possible selective abrasion of cores during drilling and the staining of graphite during sampling in excavating operations. It has to be considered comparative feasibility parameters and timing of exploration options.

The main prospecting (or exploring) excavation works run to the full thickness of the graphite accumulation or beds of certain deposit and deepening into the underlying rocks by a distance depending on the nature of contact with the host rocks and the thickness of the graphitization zone. Where there are indications that other graphite horizons or deposits may be detected in underlying rocks, about 5% exploring holes, but not less than 6-10 excavation works including bore holes should cross potentially productive accumulations at its full thickness.

4.5. The boreholes shall produce a maximum recovery of well-preserved core to the extent length allowing to determine, with the necessary completeness, the abundance of graphite bodies and the host rocks, their thickness, internal structure, the nature of the alteration in near-ore bodies, distribution of natural varieties of ores, their texture and structure, and representation of the material for sampling. In geological exploration, it has to establish that the core recovery for these purposes must be at least 90% for each drilling run. The reliability of the determination of the linear output of the core should be systematically checked by weight or volume. The magnitude of the representative output of the core to determine the content of graphite and the thickness of the production intervals must be confirmed by studies of the possibility of its selective abrasion. Graphite has low-hardness and well-distributed sheet-like scales and small crystalline grains that are highly to be eroded during drilling and be discarded in the drill mud, leading to selective erosion of the core.

For this purpose, it is necessary to compare the sample results of the core and drill mud (at intervals with their different core recovery) with the sampling data taken from controlling excavation works and drilling efficiency will also be reviewed and verified.

If it is determined that selective erosion is occurring in the core based solely on the results of the excavation or underground pit work; the data of core samples taken from drill holes will be corrected using correction factor.

If core selective erosion has been occurring during drilling procedures, all precautions should be taken to prevent it. These include optimizing drilling technology regimes, improving core recovery, using double column tubing (core-tube technology) and ejector equipment, and changing drilling methods. Due to different physical properties between graphite and graphite-bearing rocks, rotary drilling methods are preferred in exploration drilling procedures; and the percussion and reverse circulation drilling methods should not be used in exploration drilling.

Although the core recovery of rotary drilling rigs currently used for exploration of graphite deposits has significantly improved, the probability of selective erosion in core is reduced, but research in this area is necessary.

4.6. In order to increase the reliability and informativeness of drilling, it is necessary to use methods of geophysical down hole logging in boreholes, whose rational complex is determined on the basis of the set objectives, specific geological and geophysical conditions of the deposit and modern possibilities of geophysical methods. The system of downhole logging, which is effective in determination of production intervals and setting their parameters, must be carried out in all boreholes drilled in the deposit. The validity of the logging data must be confirmed by a comparison with the well drilling results for the main types of ore in the deposit, at intervals with a high recovery of the core, for which no selectivity is proven, if the requirements of the relevant instructions on geophysical methods are met and the materials supporting their validity are available. The reasons for the significant discrepancies between geological and geophysical data should be identified and reported in the reserve estimation report.

In vertical boreholes with a depth of more than 100 m and in all inclined boreholes, including underground boreholes, the azimuthal and zenith angles of the boreholes shall be determined and verified by reference measurements at intervals of not more than 20 m. The results of these measurements should be considered in the compilation of geological profiles, plan maps, underground excavation works and in calculation of thickness of production intervals. If there are observed intersections of boreholes to adit or underground excavations, the results of the measurements shall be verified by underground surveyors tying data. For boreholes it is necessary to ensure that they cross the ore bodies at least 30°.

Artificially curved boreholes are useful for crossing graphite ore bodies in a vertical or with a steep slope position at high angles. In order to increase the efficiency of exploration, multiple (branch-like) boreholes should be drilled and, in the case of mining horizons, underground borehole should be drilled from a collar to multiple directions. It is advisable to drill by ore with one diameter.

4.7. Mining operations (excavation works) are the primary instruments of carrying out detailed studies of the bedding conditions, morphology, and internal structure of graphite deposits, their continuity, the material composition of ores, the distribution of major components and allowing to conduct main controls on drilling data, geophysical studies and technology sampling. At Group III deposits, underground mining is the main instrument for detailed exploration of the structure of the deposit (area).

In this type of deposit, the underground mining excavations will be used in the main part of the deposit, which is mined in first order and has the potential to represent the ore and ore bodies that can be mined in the future.

Underground exploration excavations will be carried out along the strike of a normal ore body, and along with the slope of the steep body, clarifying morphology of the ore body and the spatial distribution of graphite, and assessing the discontinuity and spatial changes mineralization.

Thin graphite ore bodies are traced by adit and shaft with systematic sampling from the walls step by step. The length of samples has to be confirmed experimentally or by the development of a given or similar deposit. A density of ports, cross-tunnels and underground boreholes is involved in the study of large deposits.

One of the most important purposes of mining operations is to determine the degree of selective erosion in samples taken from the core during drilling in order to determine whether borehole testing and geophysical studies can be used for geological correlations and reserve estimations. Mining excavation works should take place in the areas of detailed studies and the mineable horizons of the deposit, which is operated in primary order.

4.8. The location of exploring excavations and distances between boreholes (exploration work grid) should be determined on a case-by-case basis, considering the geological features of the deposit. Although there are many ways to optimize the density of an exploration grid for any mineral deposit, the comparative method is widely used in exploration practice. Its essence is that it is determined the density of the exploration grid for the used in similar deposits, which explored previously and identical in geological setting, shape, size and position of the ore body, the spatial distribution of minerals in the ore body, and the thickness of the ore body that can be compared to the deposit being explored and making relevant optimizations in comparison.

Parameters demonstrated in the Table 1 are generalized information on grid densities used in the exploration of graphite deposits in the Commonwealth of Independent States (CIS) including Russia based on long-term experience in exploration and mining of many graphite deposits, and experience in exploration of minor graphite deposits in Mongolia. The following table shows the possible variants of the density of the exploration grid corresponding to the complexity group of geological setting and explored reserve/resource level of graphite deposits.

The density information of the exploration grid given in the table can be selected and used for the comparative study at the stage of project development for exploration of graphite deposits. However, it should be noted that this does not necessarily mean that such a dense grid should be used for exploration.

Summary of exploration grid density for the exploration of graphite deposits

Table 2

Deposit Group	Description of ore bodies	The main type of exploration workings	Distance (in m) between workings (boreholes and excavations) corresponding to reserve categories *					
			Certified (A)		Objective (B)		Available (C)	
			Along with strike	Along with dipping	Along with strike	Along with dipping	Along with strike	Along with dipping
I	Reservoir and stratal, characterized by sustained thickness, uniform distribution of graphite carbon and slightly or undisturbed bedding: - Horizontal - Vertical or steeply dipping	boreholes, trenches and dug pits	75* to 100 75 to 100	25 to 50	150 to 200 100 to 200	50 to 75	300 to 400 200 to 300	50 to 100
II	Medium-sized deposits of stable thickness, uniform and uneven distribution of graphite carbon content, fractured and folded stratum-like and mesquite-like deposits	boreholes, trenches and dug pits	-	-	50-100	50-100	100-200	50-100
III	Medium to minor sized deposit characterized by lenticular, vein-like and seam-like bodies with unstable thickness and very uneven distribution of graphite carbon	boreholes and underground excavation**	-	-	-	-	100-200 continuous 20-40	50-100*** 50

Note: * A small number of horizontal seams are included in the widening direction.

** The distance along the extension of the underground excavation is the distance between cross-cut and cut.

*** In Group III deposits with minor stock and lenses, the distance between boreholes can be reduced to its half.

**** For evaluation of resources by grade (P1) the grid size of the possible reserve (C) category can be doubled.

4.9. In order to validate reserves, individual areas of certain deposit should be explored in greater detail in order to detail the spatial location of deposits and designated industrial (technological) types and graphite brands, internal areas with substandard ore (жишигийн шаардлага хангахгүй хүдэр) and gangue minerals, karst cavities, and faults. These areas should be studied and tested over a denser exploration density than that adopted for the rest of the deposit.

The reserves in areas and the horizons subjected more detailed studies and belonging to Group I should be explored primarily in categories A and B; and in Group II in category B, and in Group III in category C the grid of exploration works in the detailed areas should be twice as dense;

The detailed areas should reflect the conditions of the deposits and the shape of the graphite deposits containing the main deposits, as well as the prevailing quality of the ores. Where possible, they are located within the contour of the reserves to be processed as a matter of priority. Where such areas are not representative for the entire deposit in terms of geology, ore quality and mining and geological conditions, the areas satisfying this requirement should also be studied in detail. The number and size of the detail areas in the explored deposits shall be determined in each individual case by the subsoil user.

The information obtained from the areas subjected to detail studies is used to substantiate the complexity group of the deposit, to confirm the correspondence of the accepted geometry and density of the exploration grid and the chosen technical instruments of exploration to the characteristics of its geological structure, to assess the reliability of the results of the sampling and calculation of the parameters taken in the reserve estimation on the rest of the deposit and the conditions of the development of the deposit as a whole. The results of operational exploration and exploitation are used for this purpose on the deposits being under mining exploitation.

4.10. All exploration workings and boreholes as well as natural outcrops shall be properly documented. The results of the sampling are submitted to the primary sample book, and verified against the geological description.

Special attention in documentation should be paid to the characteristics of the metamorphism of graphitic rocks, composition, position, features and frequency of occurrence of veins and dikes; tectonic faulting, brittle zone and weathering zones; detailed description of graphite crystalline-level (grain size and structure), the nature of their intergrowth with other minerals, i.e. availability of sulfides, mica and clay minerals.

Completeness and quality of the primary documentation, consistency with the geological features of the deposit, correctness of the determination of the spatial position of the structural elements, the drawing of sketches and their descriptions should be systematically monitored and corrected by competent commissions (senior persons or staff appointed by the exploration organization). Special attention has to be paid to the quality of primary documentation.

The quality of the geophysical measurements and all types of sampling activities shall be controlled on a regular basis and the results shall be evaluated.

4.11. In order to study the quality of minerals, delineate graphite accumulation and reserve estimation, all ore intervals revealed by exploration or observed in natural outcrops should be properly sampled.

4.12. The selection of methods (geological, geophysical) and sampling methods (chip samples, linear, areal and volume samples, etc.) is made at the early stages of the evaluation and exploration work, based on the specific geological features of the deposit and the physical properties of the minerals and host rocks. The method and mode of sampling adopted should ensure the highest reliability of the results with sufficient productivity and economy.

If several sampling methods are used, they should be compared and evaluated according to the accuracy of the results, the validity and the ability to replace each other.

The selection of geological methods of sampling, the determination of the quality of sampling and processing, and the evaluation of the validity of sampling methods should be guided by the relevant normative and methodological documents.

In the case of the use of nuclear-geophysical methods of sampling on graphite deposits, the application of these methods and the use of the results in reserve calculation are regulated by the relevant normative and methodological documents.

The use of nuclear geophysical sampling methods in the exploration of graphite deposits, as well as other innovative new sampling methods, the physical-geological feasibility and application of methods should be discussed and approved by the responsible State Administrations for studies Mineral Resources and Nuclear Research.

In order to reduce the waste of labor and costs of sampling and processing, and properly determine the intervals and numbers of samples (core, channel and scrape samples etc.), it can be pre-determined using results of downhole logging or nuclear geophysical and other methods.

4.13. The sampling of the exploration sections shall be in accordance with the following conditions:

- The surface sampling density must be maintained determined by the geological features of the deposits and ore-bodies and is usually established on the basis of the experience of the exploration of analog deposits and, in the case of new sites, by experimental procedures; and this principle should be followed for the geological section that subjected to sampling procedures;
- the linear samples like as core and channel ones should be taken in the direction of maximum variability of the graphite carbon in the deposit along with its long side;
- in the case of intersection of graphite deposits by exploration workings (especially boreholes) at a sharp angle to the direction of maximum variability (if this raises doubts about the representativeness of sampling), control excavation works are needed for comparison, and it must verify the possibility of using the obliquely positioned sample results in these sections in reserve estimation;
- sampling should be carried out continuously, for the entire thickness of the ore body with a penetration into the host rocks by an amount exceeding the thickness of empty or sub-standard ore seam. The samples from the host have to be taken in whole exploration sections for deposits without visible geological boundaries, and along a sparse interval of workings for deposits with clear geological boundaries.

- the oxidized ores that revealed in in trenches, main trenches, dug holes and other natural outcrops have to be separately sampled;
- the length of each sample interval (single sample) is determined by the internal structure of the ore body, the variability of the substance composition, texture and structural features, physical-mechanical and other properties of ores. For graphite deposits, the length of the linear sample section is usually 1 to 2 m, and for graphite ore with evenly distributed grades and bedrock – 2 to 4 m;
- and in boreholes also the length of the drilling run should be considered when selecting the section length of the drill core sample. The length of the sample section shall not exceed the minimum thickness of the ore body, maximum thickness of host rock or internal plies that includes into producible ore, and natural and technological types of ore with standard graphite ore grades that compliant to reserve estimation.

The core sampling is common in exploration procedures on graphite deposit, due rotary drilling method is dominated in the procedures. The core shall be sawn along the axis, cut in sections, and sampled. Half of the core is usually selected in the sample.

In the case of selective core abrasion has been observed during drilling, a mud sample shall be taken from that interval along with a core sample, from each selected sampling step/run with the help of a mud collector, processed separately and sent for analysis. It is possible to fully take the sample without splitting the core from the depth drilled with small diameter and with low core recovery. If reverse circulation (RC) drilling is used in the exploration of the deposit, the rock cuttings from each drilling run will be sampled. Based on the above note, due to the physical and mechanical properties of graphite, reverse circulation drilling should not be used in the exploration of graphite deposits.

Samples from mining workings (trench, main trench, dug holes, adit, shaft, cross heading, gallery/roadway, cross-cut and shaft inset etc.) are mainly taken by channel sampling method. Different levels of oxidized ores taken from surface excavations such as trenches, main trenches and dug holes, will be sampled separately.

In the trenches, main trenches samples are taken from the bottom; before sampling, the trenches should be deepened about 10 to 15 cm into underlying rocks are opened. The dug holes can be used for exploration of graphite deposits covered with very thick loose sediments. Sampling of the pit is carried out on its walls and bottom.

In mines crossing graphite deposits, sampling is carried out continuously on one or two production walls, depending on the degree of inequality of graphite distribution.

In vertical and horizontal mining tunnels that trace the ore body in strike or dipping direction, the samples are taken from their benches. The distances between the samples in the benches and sampling parameters shall be determined by experimental work.

Due to the graphite has different physical-mechanical properties from the minerals of host rocks, soft and easily splitting mineral; it is possible collapsing from the wall during sampling and increasing the graphite grade of the sample. If such a condition is likely to occur, it should be determined by experimental studies and the use of equipment (such as a two-cutting edge circular saw) that can accurately determine the cross-section of the channel for the samples.

The sample data from excavations that did not reveal the full thickness of the graphite ore body, it cannot be used to reserve estimation for the certain block.

4.14. The quality control of sampling for each accepted procedure is regularly carried out to each step (sampling, sample processing and sample analysis, etc.) systematically and properly.

Sampling control is based on the choice of location considering the geological structure of the channel samples, the correct cross-sectional size and shape, the weight of the sample; in case of non-directional core samples, the core is divided paying attention to that the parts of the sawn core have equal graphite grade, and taking control on the proper selection of sample to dispatch. If necessary, the controlling procedures can be taken repeating from next to the main channel sample, and repeating the sample from the remaining half of the core duplicate.

In the case of repeated sampling, the error rate is usually estimated at a certain percentage limit (10-20%), considering the difference in density of graphite ore and host rock.

During geophysical sampling in natural occurrences, the stability of the equipment and reproducibility of the method and sample positions are controlled under the same conditions of ordinary and control measurements. The validity of a geophysical test is determined by a comparison of geological and geophysical data from the reference intervals with a high yield of the core, for which it has been proved that there is no selective abrasion.

The validity of the methods adopted for sampling boreholes and mining operations can be monitored in a more representative manner by bulk sampling, in accordance with the relevant methodological documents. For this purpose, it is also necessary to use data from technological sampling, and bulk samples taken to determine the volume weight (density) in the mining excavations.

The amount of controlling re-sampling procedures shall be sufficient to statistically process the results and substantiated findings of systematic errors and, if necessary, to apply correction factors.

4.15. Samples shall be processed in accordance with designs developed for each deposit or taken in analogy to similar deposits. Basic and control samples shall be processed in the same way.

The quality of the sample processing should be systematically monitored for all operations with regard to the validity of the K coefficient, compliance with the sample processing scheme, and the avoiding of segregation process like as enrichment and decomposition of samples during the sample processing procedures (by contaminating sample materials due to clean up of crushers, sieves and mills etc.). For graphite ores, the K coefficient is generally 0.05 for homogeneous ore and 0.1 for non-homogeneous ore.

The main control of the sample processing is conducted to the sample that composed of the collected waste from the sample reducing process, reprocessing the sample using the same method as the main sample for analysis and control. In this case, the number of control processing should be sufficient for statistical evaluation of the error.

4.16. The chemical composition of graphite ore needs to be examined in a comprehensive manner that provides a reliable assessment of its quality, the identification of harmful impurities and related components, taking into account the proposed industrial uses, for all indicators established by the requirements of the relevant State standards, technical conditions and approved conditions.

The analysis of the samples taken from graphite ore is mainly carried out by chemical, physical-chemical, spectral and other methods; this shall be done in accordance with the norms and standards applicable to the analysis.

All samples are analyzed for graphitic carbon, clayey and siliceous contents and moisture.

In the case of metamorphic deposits containing altered limestone and calcined metamorphic rocks, in addition to graphite carbon, carbonate carbon must be identified. Some parts of the ordinary samples are analyzed on S, Fe, Cu, Co, Pb, Ni, As and volatile matters. The number of these analyzed samples should be sufficient showing the change in the chemical composition (elements and volatiles) of the graphite ores by the thickness of the geological sections or deposits.

The content of these components, the yield of volatile matters, and the hydrogen value (pH) are also determined by composite samples to determine the pattern of their change over the entire deposit. Composite samples should be compiled for the complete intersections of individual graphite ore types from the ejected duplicates of ordinary samples with the same degree of grinding and should characterize the deposits uniformly, both in strike and dip directions. The size of the ejected samples taken from the duplicates of each individual sample shall be proportional to the length of the corresponding sampling interval; and the natural types of ore should be fully participated in the composite sample.

The integration of ordinary samples, the total number of bulk samples as borehole as the number of components identified in them should be justified on a case-by-case basis on the basis of the deposit structure and industry requirements.

The study of the accompanying components in graphite ore is carried out in accordance with the “Methodological Recommendations for the Complex Study of Mineral Resource Deposits and the Estimation of Accompanying Mineral Component Reserves” to be developed in Mongolia. As such recommendations have not yet been developed, similar recommendations can be used, such as Russia's “Methodological Recommendations for the Complex Study of Deposits and Reserve Estimation of Accompanying Mineral Components and Components” developed in 2007.

The graphite ores for all recommended uses and host rocks have be passed through occupational radiation tests.

If the radiation dose exceeds the established norms and standards, the issue of whether to mine the graphite ore shall be regulated by a joint decision of Radiation Control Organization and the state central administrative organization of Mongolia responsible for mineral exploration and mining.

4.17. Special attention should be paid to the fact that the majority of sampling errors belong to sample analyses, which comprise of two types of errors: random and systematic (regular).

The control on sample analyzing procedures should be carried out regularly in accordance with established methods and techniques. The regularity of the control on analyses is carried out in two main ways: once for each certain number of samples and for a certain period of time (weekly, monthly, etc.). Usually a control variant is used for every 20-30 samples.

The geological control of sample analyses should be carried out independently of laboratory internal control throughout the exploration period, by exploration and mining operators of the deposit. The results of the sample analyses are to be controlled for all major components, accompanying components and harmful impurities. All samples with a very high content must be included in the internal control.

4.18. To determine the random errors, it is necessary to carry out internal controls by analyzing encrypted test samples taken from duplicates of analytical samples in the same laboratory that performs the major analyses no later than the next quarter (3 months). This is also called internal control.

In order to identify and evaluate possible systematic errors, an external control should be carried out in a laboratory with a control status. Duplicate samples from the main laboratory that have undergone internal control are sent to external control. Where there are reference samples (RS) similar to the samples under studies, external controls should be carried out, including them in encrypted form in a dispatch of samples to be analyzed by the main laboratory. Recently, this method has been widely used, with 1 standard samples, 1 to 3 blank samples (prepared from non-mineralized bearing rock), and 1 duplicate sample for a group consisting of 20 to 30 samples being analyzed as a batch sample.

Samples sent for external inspection should be representative of all ore types in the deposit and of the content classes.

4.19. The number of samples for internal and external controls should ensure that the sample is representative of each content class and period of analysis (quarter, year etc.). When assigning classes, the condition parameters for calculating reserves should be taken into account. For a large number of samples to be analyzed (1,000 or more per year), 5 per cent of the total samples will be subjected to a control analysis, and for a smaller number of samples for each sample class, a minimum of 20 to 30 control analyses over the control period must be performed.

4.20. External and internal control data for each class of contents are processed by periods (quarter, year etc.), separately for each method of analysis and for the laboratory performing major analyses.

The calculation of random and systematic discrepancies that occurred in the internal and external control analyses shall be carried out in accordance with commonly used methodologies.

The relative mean of standard deviation determined by internal geological control shall not exceed the allowable values. Otherwise, the results of the basic analyses for the class of contents and the period of operation of the laboratory are discarded and all samples are subject to re-examination with an internal geological control. At the same time, the main laboratory must investigate the reasons for the errors and take measures to eliminate it.

Permissible limit value of the relative standard deviation corresponding to the carbon content of graphite

Table 3

No	Graphite carbon grade, %	the relative standard deviation, %
1	1 to 5	15
2	5 to 10	8
3	10 to 20	5
4	20 to 40	3
5	> 40	2

In the event that external controls reveal systematic discrepancies between the results of the tests of the main and control laboratories, an arbitration check is carried out to certified laboratory (with the status of an arbitration). In arbitration laboratory, selected minimum 30 samples are to be checked for each class of content. If the arbitration laboratory finds systematic discrepancies, based on the calculation results of the both of sample analysis, the correction factor shall be calculated and the issue of whether to use it shall be decided.

In the case of standard control samples, blank samples and duplicate samples are used for the control analyses, it shall be concluded that the analyses result of these samples fall within the error range of $\pm \sigma$, $\pm 2\sigma$, $\pm 3\sigma$. Here "σ" is the standard deviation. Irrespective of the error, the limit value is selected from time to time depending on the variability of the content of relevant content under the study. If a standard sample analysis reveals a systematic error, 10-15 standard samples will be analyzed in an arbitration laboratory to determine the error and act to correct it. The introduction of correction factors is not permitted without an arbitration analysis.

4.21. Mineral composition of ores, textural-structural specifics and physical-mechanical properties should be studied using mineralogic-petrographic, physical, chemical and other types of analysis according to established methods and techniques.

Along with the description of individual minerals contained graphite ore using mineralogic-petrographic methods, their distribution is also quantified. Particular attention should be paid to determine the particle size, color, gloss, flexibility, growth characteristics, intergrowth with other minerals, and the presence of sulfides and clay minerals in graphite. Mineralogical studies should examine the distribution of the main and accompanying components and useful and harmful impurities, determining balance of contents in form of the mineral compounds.

4.22. The volume weight (density) and humidity of the ore are the main parameters used in the reserve estimation of deposits, and must be defined for each natural variety of ores and for internal gangue mineral beds and substandard substandard ore beds.

The volume weight of massive and dense ore is determined in laboratory condition mainly on paraffin-coated representative ore-specimens measured by hydrostatic weighing method.

For determination of volume weight of loose, strongly cracked, and cavernous ores, it is more plausible to determine the weight of the loose ore taken from digging pits with well-known volume and comparing the weight of the ore to the well-measured volume of the excavation.

Also, volume weight of loose graphite ore can also be determined by absorption of scattered gamma radiation, if the required amount of verifying excavation is available.

At the same time as the volume weight (density) is determined, the humidity of the ores is determined on the same mass, at first. And on the same sample, it has to be analyzed main and accompanying components, which are characterized mineralogically, too.

If the volume weight of the ore has been determined by geophysical method, its results shall be verified by the method of volume weight determination on specimen; if the volume weight of the specimen has been determined by measuring, the results reliability shall be verified by means of a volumetric measure taken on pit excavation.

4.23. Studies of chemical and mineral composition, texture and structure and physical properties of graphite ores should identify the natural varieties of raw materials of the deposit, and allowing to choose proper enrichment methods and enrichment technology (industrial) regimes for the graphite ore processing.

The final classification of industrial types and grades of raw materials is made on the basis of the results of pilot test.

Four. Studies of ore technological properties

5.1. The technological properties of ores are generally studied under laboratory and semi-industrial conditions on mineral-technological, small-technology, laboratory, large-scale laboratory and semi-industrial samples. Due to the use of high-precision modern techniques in ore pilot testing, today the types of technological samples are mainly from laboratory and semi-industrial technology samples and realized by related technological (pilot) tests.

With the available experience in industrial processing of ore shows that the study of the technological properties of easily enriched graphite ore can be carried out by laboratory technology experiments based on the comparison of the results of pilot test on graphite ore with similar technological properties.

For hard-to-enrich or new types of ores with no experience in processing, the pilot test on ores and, if necessary, their enrichment products should be carried out under special programs agreed with interested organizations such as explorers, mining operators and ore concentrate consumers, and determining the quality parameters of the ore enrichments.

Sampling for pilot test at different stages of geological exploration should be carried out in accordance with the recommendations for technological samples. If this type of recommendation has not yet been developed, a similar methodological recommendation can be used, such as the Russian “Technological Sampling in the Process of Geological Exploration, 1998”.

5.2. In order to distinguish technological types and varieties of ores, geological and technological mapping is carried out, in which the density of sampling sites is selected according to the continuity and frequency of discontinuity of natural types of ores.

Recommendations for technological mapping of graphite ores have not yet been developed, so the recommendations of the Russian Federation (Geological and Technological Mapping, 1998) can be followed.

Mineral-technological and small-technological samples are selected over properly (evenly) selected density, and should describe all-natural ore varieties found on the deposit. On the basis of the results of their tests, geological and technological typing of the ore with the identification of industrial (technological) types and varieties of ore is carried out to the deposit; and it will be studied the spatial variability of the material composition, the physical-mechanical and technological properties of ores within the defined industrial (technological) types and drawn up geological and technological maps, mining horizon's map and sections.

5.3. The technological properties of all-type of ores (oxidized ore, primary ore, etc.) must be tested on laboratory- and large-scale laboratory samples, to choose the optimal processing scheme, and to determine the main technological indicators for the quality of enrichment and quality of the expected products.

At the same time, it is important to determine the optimum degree of grinding of ores, which will ensure maximum yield of graphite and other valuable minerals with minimum loss in the tailings and generation of mud.

At present, a pilot test is not distinguished as laboratory- or enlarged laboratory test, but the pilot test can be conducted to samples of different characteristics depending on the ore technology types of the deposit and their enrichment characteristics in laboratory condition.

For graphite ores and new types of ores that are particularly difficult to enrich, the results of laboratory pilot testing procedures should be verified by pilot tests that conducted in semi-industrial circumstances. In addition, the semi-industrial pilot test will be conducted on the ore to determine the optimal technological regime for the construction of a graphite ore processing plant.

Semi-industrial pilot tests are conducted by ore technology types. If the technological schemes of concentrating different types of natural ore are the same, a mixed sample shall be obtained from samples in proportion to the amount of natural ore types to be mined and processed, for the semi-industrial pilot test. Samples for semi-industrial pilot test shall be carried out according to a specially developed program. The semi-industrial pilot test monitors the technological regime of graphite ore enrichment process, feasibility study of the enrichment, and whether the products meet the technical norms, quality requirements and standards.

Semi-industrial technology test sampling and testing activities shall be developed jointly by the exploration and mining operators of the deposit and engineers and technicians of the testing organization and shall be carried out in accordance with the program approved by the professional inspection organization.

The sampling for the semi-industrial pilot test is taken in accordance with a program developed by the organization or persons performing exploration, mining operation and technological research, in conjunction with the subsoil user and agreed with the project organization, and approved by a professional inspection organization.

Samples for the tests by the aggregated laboratory and semi-industrial pilot test must be representative, i.e. of the chemical and mineral composition, textural-structural, physical-mechanical and other characteristics of the average ore composition of the industrial (technological) operation type, considering possible impurities that occurring due to mining operation and ore enrichment. Therefore, the samples for the studies by the aggregated laboratory and semi-industrial pilot tests include interlayers of gangue minerals and substandard ores that can be mined due to their thickness fitting to the minimum standard thickness.

In order to assess the technological properties of deep located ores that are difficult to access for mass-representative samples for semi-industrial pilot test, the observed regularities in the quality of graphite ores in the upper studied horizons should be used, and the mineral and technological studies of small samples should be drawn.

5.4. Graphite ores are typically enriched by flotation. Without prior enrichment, only selected varieties of rich ores are used (Tas-Kazgan deposit, Uzbekistan and Noginsky deposits, Russia).

The effectiveness of the graphite ore flotation depends on the crystallization degree of graphite. The clear crystalline graphite ores of Taigin, Botogol, Zavallievsky and Tas-Kazgan deposits, after their grinding, is almost entirely extracted into the foam product at a low collector reagent consumption, which makes it possible to obtain standard concentrates from the ore even with a carbon content of 2-3%.

5.5 The crypto crystalline graphite ores (e.g., Noginsky deposit) are poorly floated; significant part of the graphite remains in the tails, resulting foam product is difficult to bring to standard quality. Therefore, such ores are usually used without prior enrichment. They should have a carbon content of at least 70%, while poorer ones are rarely used.

In order to improve the quality of the crypto crystalline graphite ores, ore sorting is used. Sometimes good results are obtained by selective grinding stage by stage.

High-purity graphite is produced by refining high-grade graphite powders via burning it at high temperature using blowing gas-thermal method. This method is based on the fact that at a high temperature (2200-2500ºC) almost all ash impurities (mica, quartz, field spars etc.) evaporate. Some graphite is also lost. Sometimes expensive chemical enrichment is carried out with hydrofluoric, sulfuric or hydrochloric acid to obtain special low-ash (pure) graphite.

5.6. There is no unified industry requirement for natural graphite ores. The industry requirement is stated according to the conditions established for each deposit on the basis of technical and economic baseline studies for their extraction and enrichment.

Standards and specifications are only developed for graphite powders/pulp and concentrates (see Appendix-2).

The quality of concentrates should be determined on a case-by-case basis by a contract between the supplier (mine) and the consumer or in accordance with existing standards and specifications established for graphite powders/pulp and concentrates.

The following table demonstrates the requirements for types and grades of graphite by their application sector (Table 4).

Graphite types, marks and main applications

Table 4

Mineralogic type of graphite	Types of graphite applications	Brand of graphite	The main sectors of industrial consumption
Crystalline graphite	Special type of graphite with low ash	ГСМ-1, ГСМ-2	Production and export of special purpose products
	Graphite for batteries	ГАК-1	Manufacture of special purpose batteries
		ГАК-2, ГАК 3	Manufacture of alkaline battery's active parts, graphity antifriction products made of non-ferrous metals
	Pencil graphite	ГК-1	For pencils for drawing and stationery groups
		ГК-2, ГК-3	For stationery, school and copy pencils
	Lubricating graphite	ГС-1	For antifriction components in solid lubricating coatings in the manufacture of nuclear reactors, mechanisms of spacecraft, aircraft, as well as for colloidal-graphite preparations
		ГС-2, ГС-3	As an ingredient in current conductiving rubber, powder metallurgy products, graphite grease sticks and pastes, current conductive polymer films
		ГС-4	For the manufacture of greases for open gears of rolling mills, vehicle springs and other highly loaded friction units
		П	For the manufacture of products for special purposes
	Electrocarbon graphite	ЭУЗ-М, ЭУЗ-II, ЭУЗ-III,ЭУТ-1, ЭУТ-II, ЭУТ-III	For the production of electrocarbon products
	Crucible graphite	ГТ-1, ГТ-2, ГТ-3	For the manufacture of refractory graphite-ceramic products
	Battery graphite	ГЭ-1, ГЭ-2, ГЭ-3, ГЭ-4	For the production of primary chemical current sources
	Metallurgy graphite	ГЛ-1	For dusting the working surfaces of molds and cores when obtaining castings of a complex configuration, requiring a particularly clean surface
		ГЛ-2	For dusting the working surfaces of molds and cores when receiving castings of medium complexity
		ГЛ-3	For dusting when receiving castings that do not require high surface cleanliness
Cryptocrystalline graphite	Electrical coal graphite	ЭУН	For the production of electrical coal products
	Foundry graphite	ГЛС-1, ГЛС-2, ГЛС-3, ГЛС-4	For the manufacture of non-stick coatings when receiving castings

5.7. Ash content and sieve composition are standardized for all brands of graphite. For specific types of consumption, additional quality Indicators are normalized, shown in Table 5. The limiting values of these Indicators and other requirements for the quality of graphite are regulated by the corresponding state standards, as well as technical conditions for certain areas of use or raw materials of certain deposit.

Additional Normalized Graphite Quality Indicators for specific consumption and brands

Table 5

Type of graphite	Graphite brand	Indicator
1	2	3
Special graphite with low ash	ГСМ-1, ГСМ-2	Weight percentage of volatile matter and moisture
Pencil graphite	ГК-1, ГК-2, ГК-3	Weight percentage of volatile matter and moisture
Graphite for batteries	ГАК-1, ГАК-2, ГАК-3	Weight percentage of chlorine ion, iron, moisture, pH
Lubricant graphite	ГС-1, ГС-2. ГС-3 ГС-4, П	Depending on the purpose, weight percentage of sulfur, volatile matter, moisture, pH, dispersed composition
Electrocarbon graphite	ЭУЗ сортов М, II, III; ЭУТ сортов I, II, III; ЭУН	Weight percentage of sulfur, iron, volatile matter, moisture, specific surface area (only for ЭУТ brand)
Crucible graphite	ГТ-1, ГТ-2, ГТ-3	Weight percentage of iron, volatile matter, moisture
Battery graphite	ГЭ-1, ГЭ-2, ГЭ-3, ГЭ-4	Weight percentage of copper, cobalt, lead, nickel, arsenic, moisture, volatile matter
Metallurgy graphite	ГЛ-1, ГЛ-2, ГЛ-3, ГЛС-1, ГЛС-2, ГЛС-3, ГЛС-4	Weight percentage of moisture

5.8. The technological properties of ores should be studied in detail to provide basic data sufficient for the design of a process for their enrichment and reprocessing with the complex extraction of their components having industrial importance.

Industrial (technological) types and varieties of ores should be classified by standards, and their basic processing parameters for enrichment and chemical processing (yield of concentrates, their characteristics, extraction of valuable components in individual operations, end-to-end extraction, etc.) are determined.

The reliability of the data from the semi-industrial tests is evaluated on the basis of the technological and commodity balance. The difference in the weights of graphite between these balances shall not exceed 10%, and it shall be distributed proportionately in concentrates and tails. Processing indicators are compared with those obtained at modern graphite ore processing plants.

In order to comprehensive study and exploit the mineral resources, the studies of the accompanying minerals should be conducted in accordance to relevant methodical recommendations. If this type of guideline has not been yet developed, a similar one can be used, for example, the Russian “Methodological Recommendations on Complex Study of Deposits and Reserve Estimation of Accompanying Mineral Reserves and Components, 2007” (“Методические рекомендации по комплексному изучению месторождений и подсчету запасов попутных полезных ископаемых и компонентов, 2007”). There is a need to find out the types and brands of accompanying minerals, and their forms and distribution balance in middling and concentrate products during ore-dressing processes, and to determine the conditions, feasibility and cost-effectiveness of their extraction.

It should be studied the use of recycled water and waste from the planned technological scheme for the sample processing plant, and to give recommendations on cleaning the wastewater.

5.9. High-grade and coarse-grained ores can be extracted by hand sorting and radiometric sorting methods, then standard quality products can be yielded, and the tailings can be fully grinded and floated.

Poor graphite ore (content ~ 3-5%) is enriched by flotation. The floating ability of graphite depends on its crystalline size, the nature of the mixture, and the degree of surface oxidation. It is usually floated with soda, lime, or sulfuric acid to form an alkaline (pH 8-10) or acidic (pH 4-5) medium and to use a foaming agent (pine oil, T-80, etc.).

Five. Study of hydrogeological, engineering-geological, geotechnical, geo-ecological and other natural conditions of deposit

6.1. 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.

6.2. 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. 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.

6.3. 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.

6.4. 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.

6.5. 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.

Particular attention should be paid to the assessment of tectonic faulting and increased fracturing zones, thickness, degree and nature of brittle rocks and ores, states of fracture filling, assessment of the probability of water intrusion via fractures along with strike and dipping directions, the assessment of the structural blocky subdivisions of rock massif.

In areas with the development of perennial frozen rocks, it is necessary to establish their temperature regime, the position of the upper and lower boundaries of the permafrost sequence, the contours and depth of talik (layer of year-round unfrozen ground that lies in permafrost area), the nature of changes in the physical properties of the rocks during thawing, depths of seasonal defrosting and freezing.

The engineering-geological studies should provide data related to predictive assessment of rock stability in the roof of underground mines and the sides of open pit and their main parameters for further calculation.

If there are operating active mines or open pits in the region under similar hydrogeological and engineering-geological conditions, their parameters of hydrogeological and geo-technical conditions can be used into the current ore deposit on correlation way.

6.6. Graphite deposits are operated by open pit and underground mine. 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.

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.

6.7. For deposits where the natural gas-bearing (i.e. methane, hydrogen sulfide, etc.) sediment is observed, it has to be studied the regularity of changes in the content and composition of gases by area and depth.

6.8. Factors affecting human health (pneumoconiosis, increased radioactivity, geothermal conditions, etc.) should be identified.

6.9. Areas with no mineral deposits for industrial and residential purposes, tailings ponds and spoil bank should be identified for new mining areas. It has to conduct a study on local construction materials and determine the direction and possibility of using stripped overburden.

6.10. The main objective of geo-ecological studies is to inform the development of a project for mining and ore-processing plants on the deposit with regard to environmental protection measures.

Environmental studies should establish environmental background parameters (level of radiation, content of surface water, groundwater and air, determination of soil cover, vegetation and wildlife, etc.), to define the expected chemical and physical impacts of the proposed facility on the natural environment (dust of adjacent areas, pollution of surface water, groundwater and soil with drainage water from mine and liquid industrial waste, pollution via air emissions to the atmosphere, etc.), to determine withdrawals for the production of natural resources (forest, technical water, local construction materials, land for main and auxiliary production, mine village, pile of stripped soil and produced waste rock, and substandard ores, etc.), and to assess the nature, intensity, degree and risk of impact, and the duration and dynamics of the sources of pollution and their impact zones.

In order to solution of land reclamation issues, it should be determined the soil thickness and conducted the agrochemical studies of loose sediments, and investigated the toxicity and potential for revegetation on the land. Recommendations should be made for the development of measures for the protection of the soil, the prevention of environmental pollution and the reclamation of the land.

6.11. Hydrogeological, engineering-geological (geo-technical), geocryological, mining-geological and other natural conditions are studied in detail to provide the baseline data necessary for the development of the mining project. In the case of particularly complex hydrogeological, engineering-geological and other natural conditions of exploitation requiring special works, the scope, time and procedure for carrying out research are agreed with and between the subsoil users and project implementing organization.

6.12. Other mineral resources that are contained in form of separate accumulations within the host rocks and overburden of the deposit should be explored to the extent possible to determine their commercial value and area of possible use in accordance with requirements of established methodical guideline. In the absence of such kind of guidelines, a similar recommendation can be used, i.e. Russian "Recommendations on complex studies of deposits and reserve estimation of accompanying minerals and components, 2007".

Six. Reserve estimation

7.1. 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".

7.2. 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 graphite 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.

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

The certified (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 objective (B) class 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 Class 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 objective (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 available (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 class 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 class 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.

Determined (P1) class 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 (P1) 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.

7.4. 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 approved (A ') and assumed (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”.

7.5. In use of extrapolation line, the width of the extrapolation zone in each case for categories B and C reserves needs to be supported by factual data. Extrapolation should not permitted towards faults, the pinching out and splitting of ore bodies, the degradation of graphite ore quality and deterioration of the mining and geological conditions for their exploitation.

7.6. 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.

7.7. 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.

7.8. 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).

7.9. 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.

7.10. 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 byGeostatic 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.

7.11. 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.

7.12. 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”.

7.13. 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

In terms of the degree of studies of the graphite deposit (area of larger deposit) may be classified in following way:

- assessed mineral deposit (area); and
- explored deposit (area).

The study degree for the assessed deposits determines the advisability of continuation of exploration work at the deposit/site, for the explored - the preparation of the deposit for industrial development.

8.1. 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 available (C) classification and the rest of them is assessed as determined resource (P1).

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.

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.

8.2. 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.

Reference materials

Relevant instructions and recommendations

1. “Content and requirements for the report on the results of mineral exploration work”. Order No. 114 of September 9, 2009 of the Director of the Mineral Resources Authority.
2. “Classification and guideline for mineral resources and deposit reserves”. Order No. 203 of the Minister of Mining dated September 15, 2015.
3. “Instructions and requirements for conducting hydrogeological survey of the deposit during mineral exploration”. Order No. A / 237 of the Minister of Mining and Heavy Industry of Mongolia dated December 12, 2017,.
4. “Methodological recommendations for applying the classification of mineral resources and deposit reserves to the certain minera resourcesl” (Appendix 2 to the Order No. 195 of the Minister of Mining and Heavy Industry dated August 13, 2018*6
5. “Instructions for performing and reporting electrical, magnetic, gravimetric and aerial geophysical mapping works to be carried out in the territory of Mongolia”. Order No. A / 237 of the Minister of Mining and Heavy Industry dated December 12, 2017.
6. “General principles for construction engineering research”. Norms and rules / Building standards and rules of Mongolia (BNbD 11-07-19). Order No. 138 of 2019 of the Minister of Construction and Urban Development.

Relevant other materials

1. Baryshev N. V. Control of sampling - Materials on methods of exploration and calculation of reserves. Issue 2, M., Gosgeoltehizdat, 1948. With 88.
2. Engineering-geological, hydrogeological and geoecological studies in the exploration and operation of ore deposits. M., 2002.
3. Methodological recommendations for the application of the classification of reserves and prognose resources of solid minerals. Graphite ores. Moscow, 2007., 45 p.
4. Methodological recommendations for comparing data on exploration and mine development of solid mineral deposits, Moscow, 2007.
5. Methodological guidelines for the study of engineering and geological conditions of ore deposits during exploration. M., 2000.
6. Recommendation for the complex study of deposits and the reserves estimation of accompanying minerals and components. M., 2007, 15 p.
7. Solid minerals and rocks. Technological sampling in the process of geological exploration works, STO Ros Geo 09-001-98. Resolution of the Presidium of the Executive Committee of the All-Russian Geological Society. No. 17/6, Moscow, 1998.
8. Solid minerals and rocks. Geological and technological mapping. STO Ros Geo 09-002-98. Resolution of the Presidium of the Executive Committee of the All-Russian Geological Society. No. 17/6. Moscow, 1998.

Appendices

Appendix-1

Definition of quality change of Basic indicators of solid mineral deposits

Quantitative indicators of basic mineralization quality changes can be used to classify a deposit as a complex geological formation (Table 5). The following explanations are provided for the quantitative assessment of some of the key indicators required to classify the deposit as a complex geological formation and for the corresponding group of deposits. These include:

a. Mineralization coefficient K_x is used to separate the elementary blocks of reserves of the interrupted mineralized deposit. It is defined by the following formula:

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

Here: $l_i -$ linear size of ore parts that crosscut by cut by excavation working and borehole,

$L -$ linear size of the total parts that crosscut by cut by excavation working and borehole.

b. Coefficient of complexity of the deposit $q -$ is determined by the following formula:

$$q = \frac{N_x}{N_x + N_{xг}}$$

Here: $N_x -$ number of excavation works and boreholes that crosscut the ore,

$N_{xг} -$ number of excavation works and boreholes that did not crosscut the ore.

c. The change in the thickness of the ore body is determined by the following formula:

$$V_m = \frac{\sigma_m}{\overline{m}}$$

Here: $V_m -$ coefficient of variation of ore body thickness,

$\sigma_m -$ dispersions of ore body thickness.

$\overline{m} -$ average thickness of ore bodies.

d. Changes in the content of a useful component are determined by the following formula:

$$V_a = \frac{\sigma_a}{\overline{a}}$$

Here: $V_a -$ coefficient of variation of the useful content,

$\sigma_a -$ dispersion of changes in the content of profitable plants,

$\overline{a} -$ average content of useful content

Assessment of Deposit Complexity of Geological Settings calculated by statistical method and group correlation

Table-6

Deposit group	Deposit Complexity indicators of Geological Settings			
	K_x	q	V_m	V_a
Group I	0.9-1.0	0.8-0.9	< 40	< 40
Group II	0.7-0.9	0.6-0.8	40-100	40-100
Group III	0.4-0.7	0.4-0.06	100-150	100-150

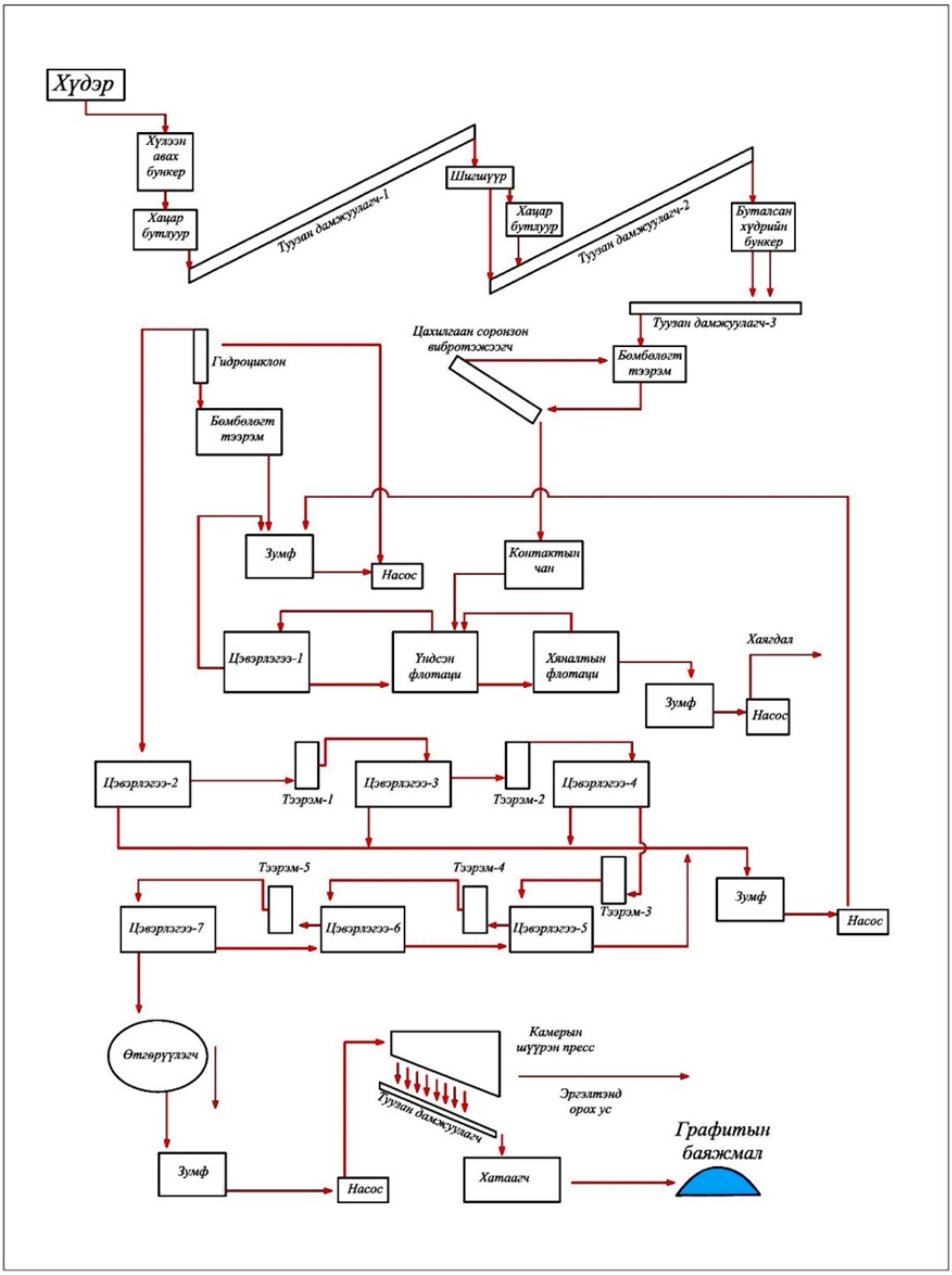
Appendix-2

Technical conditions and standards for graphite materials and products used in Russia (January 1, 2005) (Standards are in Cyrillic)

ГОСТ 4404–78 Graphite for the production of pencil pens
ГОСТ 4596–75 Crucible graphite
ГОСТ 5279–74 Cast crystalline graphite
ГОСТ 5420–74 crypto crystal
ГОСТ 7478–75 Battery graphite
ГОСТ 8295–73 Graphite for the production of paints, coatings and conductive rubber.
ГОСТ 10273–79 Graphite for active mass production of alkaline batteries
ГОСТ 10274–79 Graphite for the production of electrocarbon
ГОСТ 17022–81 Graphite type, brand and technical requirements
ГОСТ 17817–78 Sampling and preparation of graphite for test
ГОСТ 48-911–81 Construction graphite and test method.
ТУ 6-02-711–77 Dense pyrographite
ТУ 6-02-712–77 Low-density pyrographite
ТУ 16-538. 261–75 Enriched graphite
ТУ 21-25-106–73 Ukrinol-7 technology paint graphite
ТУ 21-25-108–73 Antifriction graphite for metallic ceramics goods
ТУ 21-25-156–75 Electrocarbon graphite for export
ТУ 21-25-162–75 Graphite of TAS-Kazgan Deposit
ТУ 21-25-172–75 Electrocarbon graphite from Botogol deposit, EUBA brand
ТУ 48-20-1–81 Graphite for the production of battery rods. SG and SGM brands
ТУ 48-20-4–77 Antifriction graphite. Manufacture of billets and articles. Brands: AO-1500, AO-600, АГ-1500, АГ-600.
ТУ 48-20-24–78 Graphite for the production of billets and articles. RG-CK-1 brand.
ТУ 48-20-44–74 Antifriction graphite. АГ 1500-3 brand
ТУ 48-20-45–74 Graphite for Antifriction material for production of of billets of АМС-1 и АМС-3 brands
ТУ 48-20-50–79 Antifriction graphite. ИГРАН, НИГРАН-В brand
ТУ 48-20-54–75 Powdered graphite.
ТУ 48-20-60–75 Graphite for the production of billets and articles, В-2 (1) brand
ТУ 48-20-61–75 Graphite for the production of billets and articles, РГ-ТК brand
ТУ 48-20-69–75 UPV-1 graphite
ТУ 48-20-71–76 Graphite for the production of billets and articles, АГ-Т1 марк

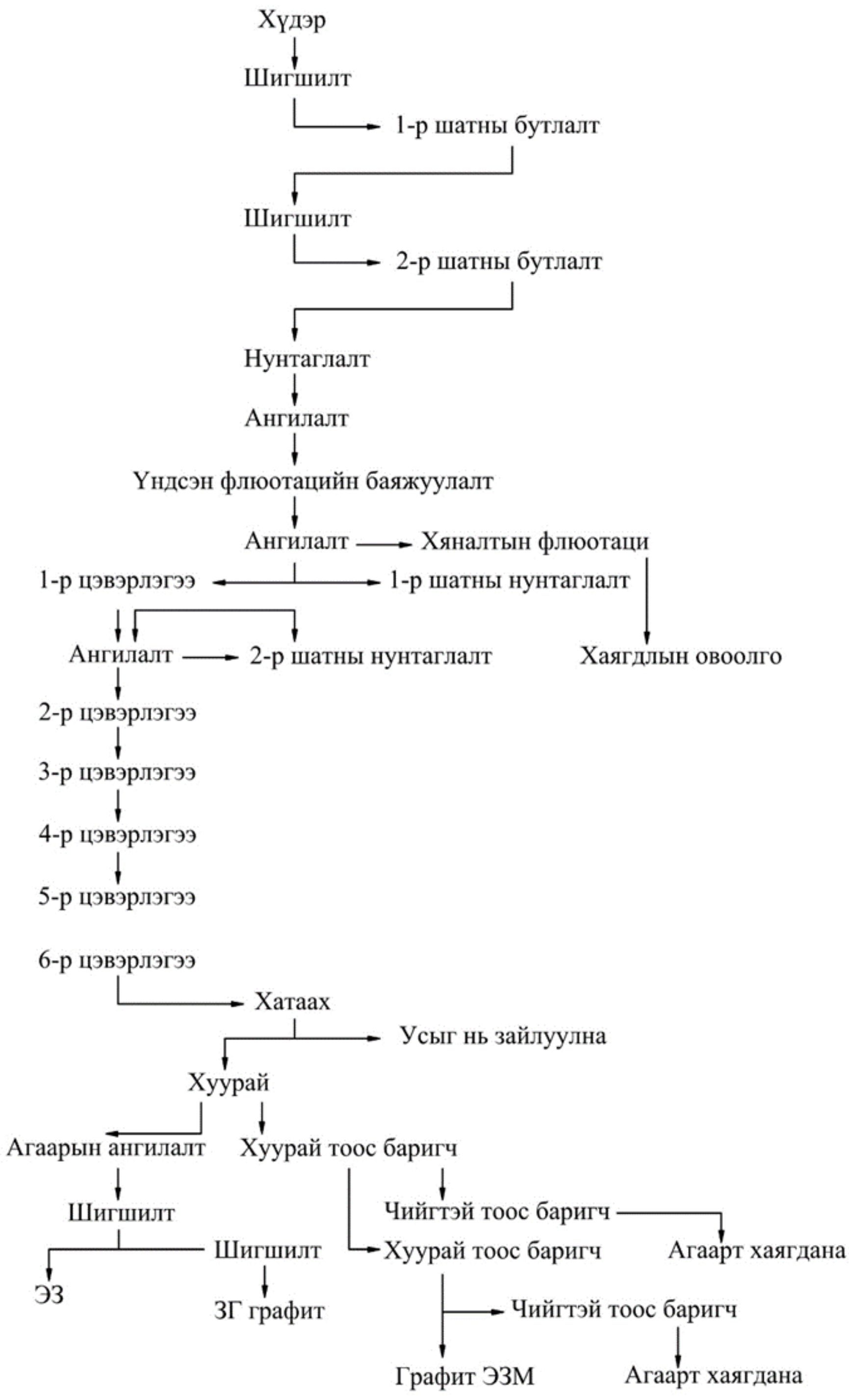
ТУ 48-20-74–76	ЛГ-3 graphite
ТУ 48-20-78–76	Graphized coal, ОСЧ-7-3 brand
ТУ 48-20-90–82	Exclusively pure graphite for the production of billets and articles.
ТУ 48-20-95–76	Antifriction graphite for the manufacture of workpieces and articles. АТГ brand

Appendix-3



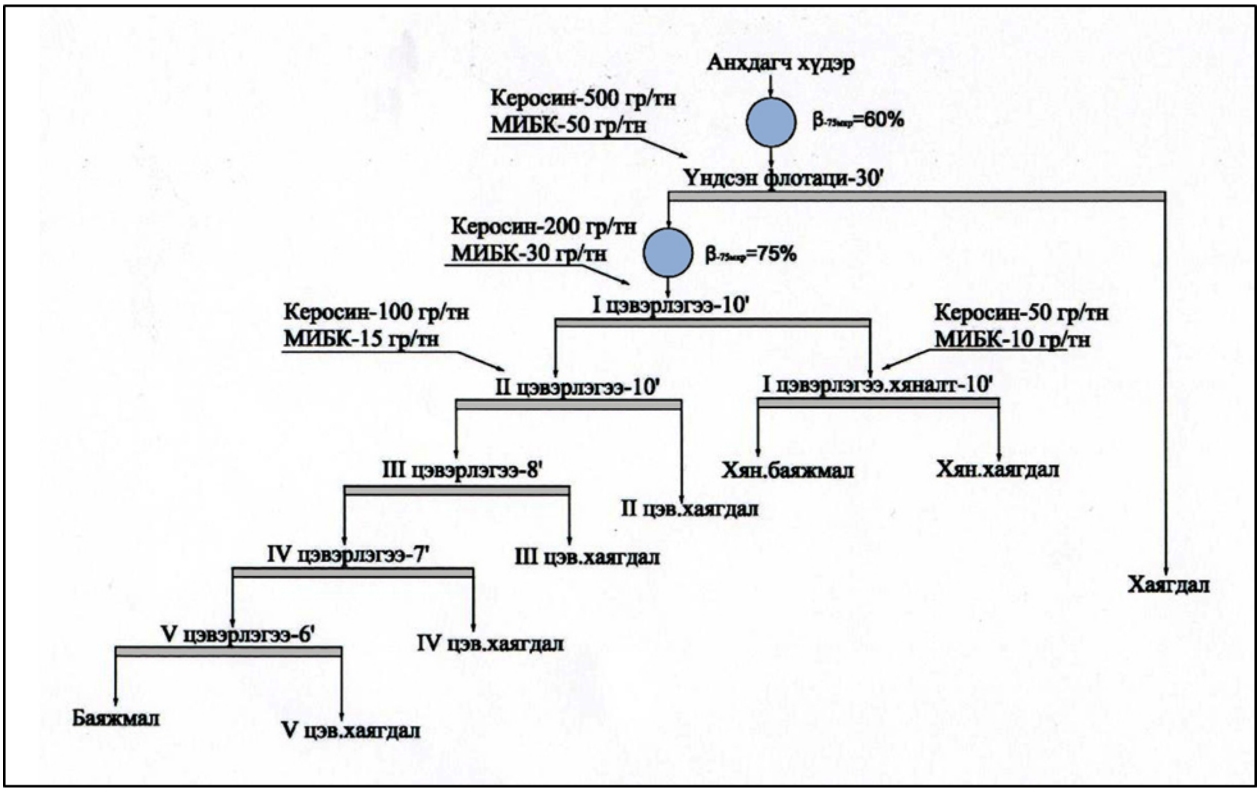
Flow-chart of graphite enrichment technology

Appendix-4



Flow chart of graphite ore processing, Zavalevsky plant, Russia

Appendix-5



Flow chart of ore ore enriching technology, Chuluut graphite deposit

GLOSSARY

Апокаменный уголь - апочулуун нүүрс – derived from hard coal

Буровой снаряд – өрмийн сум drill barrel

Водозабор – ус татах байгууламж- усан сан- water intake

Восстающий – өгсөх далд малталт

Выкрашивание графита -бал чулуу нялагдан бүрэх үзэгдэл- графитаар бүрэх

Горные выработки – уулын малталт

Изолиния – ижил утгын шугам

Избирательное истирание керна – кернийн сонгомол элэгдэл

Квершлаг - квершлаг

Контур – хүрээ

Корющие своиства- Үл автах шинж чанар

Метод – арга

Микро блок, элементар блок-нэгж хэсэгшил,

Оконтуривание – хүрээ хил татах

Пластичность-Уян налархай чанар

Пневмокониозоопасность – уушиг чулуужих аюул

Поверхностная вода – гадаргуугийн ус

Подземная вода – гүний ус

Подземные горные выработки – уурхайн далд малталт

Размер залежи – хүдрийн биет [оршдос, хэвтэш]-ийн цар хэмжээ

Рассечка – рассечка

Рельеф – газрын гадаргуу

Скорлуповатая масса- хальсархаг хэсэг

СОС буюу стандартный образец состава – стандарт найрлагатай дээж

Способ опробования – сорьцлолтын арга

Ствол скважины – цооног, цооногийн хоолой

Топографические карты- байрзүйн суурь зураг

Утилизация подземных вод- Гүний усыг эргүүлэн ашиглах

Шахт – босоо уурхай

Штольня – хэвтээ уурхай

Штрек – штрек

Эжектор – давхар ханатай өрмийн сум

Australia Mongolia Extractives Program
2A Temple View Residence
Suhbaatar District-1
Ulaanbaatar
Mongolia
T: +976 7000 8595

www.amep.mn
facebook.com/AMEP2
Twitter.com/AusMonXtractive

AMEP
Australia Mongolia Extractives Program