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Introduction into Mineral Raw Material Deposits

A natural accumulation of usable mineral commodities, which can be economically extracted based on their size and content, is called a deposit. Consequently a deposit is part of an area of the earth crust, which is promising a high yield, and in which there is a concentration of profitable components, resulting from a geological process. The quality of these profitable components has to correspond to particular required conditions, and their quantity needs to justify not only the operation of a mine, but the investment to be made for all needed operation plants for a longer period.

Basically there are several possibilities to divide raw material deposits. Fig. 1 shows a possible division, based on geological formation, content of the deposit, as well as the rock strength.

Regarding their utilization, several groups of mineral raw materials can be differentiated. Among others, these are energy feedstock, metallic raw materials, construction raw materials, as well as salts and industrial minerals.

Furthermore the division of deposits is done based on the rock strength. The differentiation can be made between hard rock deposits und soft rock deposits. There are considerable differences in extraction processes, based on the rock strength.

Looking at the formation of mineral raw materials, they are partitioned, depending upon their geological genesis. Rocks and deposits are mainly divided into three categories, which are directly connected to their genesis. These are magmatites, metamorphites, as well as sediments.

The fundamental criteria for division of deposits are presented in the following section: ➤

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**Fig. 1: Classification of Deposits**
Division of deposits, depending upon their genesis

Magmatites are formed through the cooling of fluid magmas. The cooling of the earth occurs from the surface. Under the thin and solid earth crust there exist magmas, i.e. molten material in fluid form and with high temperature. At times they come to the surface through volcanism and pour out as lava, whose normal temperature lies between 1,100°C and 1,250°C. The solid Olivin and Leucit crystals, which only melt at a temperature of 1,300°C, indicate to the fact that magma temperatures in the depths must be much higher. If magma of granitic composition leaks out from the earth surface, effusive rocks or vulcanites are formed, which cool down quickly under the influence of the atmosphere. Due to this quick cooling no big crystals can be formed and the rocks, which are formed in this way, are characterized through a fine-grained structure. Examples are Quartzzporphyry and basalts, which are fine grained to such an extent, that it is not possible to macroscopically recognize its minerals.

In case magmas solidify on their way to the earth surface, so-called plutonic rocks or plutonites are formed. They crystallize at a temperature of 1,500°C and at compressions of several thousand bars. The cooling process in these depths happens very slowly, so that the crystallized minerals can grow to big individual crystals. Therefore plutonic rocks are usually coarse-grained. As an example granite is composed of light feldspar crystals, bright quartz grains and strongly reflecting glimmer lamellae. It is possible that in the so-called volcanic pipes diamonds are formed under a very high pressure. Kimberlit, which is composed from elements Olivin, Pyrop and Ilmenite, acts as bedrock.

The formation of magmatic rocks happens in several phases. In the intra-magmatic phase, first the high melting minerals crystallize. Plutonic rocks such as Granite, Diorite and Gabbro are formed. The molten parts are separated through gravity, so that liquid magmatic deposits of Chrome and Pentlandit (Nickel ore) are formed.

In connection with the early crystallization of ultra-basic and basic rocks, deposits of Copper (Chalcopyrite), Titanium (Titano-Magnetite) Platinum and precious stones (e.g. Diamonds), as well as Minerals of the Garnet group, Peridot (Olivine) and Feldspar (Labradorite) are formed. During this crystallization process the amount of molten mass is steadily reduced. The leftover molten mass enriches itself with highly volatile substances like water, carbonic acid, hydrogen sulphide, hydrogen fluoride, hydrochloric acid, boron and beryllium, as well as with heavy and precious metals, which leads to an increase of the gas pressure.

Through the shrinking process during the cooling of the molten mass, cavities keep being formed, in which under favorable conditions volatile elements can be accumulated. In case the molten mass cools to a few hundred degrees, the cavity formation is particularly favorable. In that case the rocks are not plastically deformed, but break under the influence of the pressure, which fosters formation of fissures and faults. Due to the rising gas pressure the fluids and gases are pressed into the veins and cleavages or cracks, in which the elements can crystallize. This ongoing precipitation of minerals leads to liquid magmatic-pneumatolytic genesis.

Subsequently the second phase of the magma solidification follows, which is the pegmatic-pneumatolytic phase. With further cooling dyke rocks or pegmatites are formed out of the rest of the molten material. These are very coarsely grained rocks, which particularly stick out because of the size of their crystallized material. Pressure is still very high during the formation of these minerals, although temperatures are considerably lower at 700°C to 500°C, and only drop very slowly. The residual liquid, which has penetrated veins and cleavages or cracks, influences the neighboring adjoining rocks of the earth crust and lead to metamorphism processes, which are explained later.

The pegmatitic phase is accompanied by a pneumatolytic phase (greek: “pneuma” = gas and “lyein” = loosen). Extended dissolving processes happen in the adjoining rocks. Since the newly penetrated residual liquid is hotter than the surrounding rocks, they are again etched and dissolved. The newly smelt material reacts with the rest magma, and along with the consecutive new crystallization so-called contact rocks and contact minerals are formed. This process is called contact metamorphism (conversion through new contacts). The expression of pneumatolysis is used, because during this contact process, chemically very active, highly volatile and gaseous elements play a particularly important role. Formation of pegmatites and pneumatolysis is parallel or blended. During the contact metamorphism deposits of Tin, Wolfram and Molybdenum are formed, due to boiling- and distillation processes, in connection with changes in pressure. Contact metamorphic rocks mostly have a direction-free granular structure.

During the solidification of magma, and after the formation of plutonic rocks, dyke rocks and contact minerals or contact rocks, only water in super critical condition is left, which has a high pressure and temperatures of 350°C and contains many substances in dissolved form. While further cooling and during the flowing through rifts and cracks in the earth crust, the last phase of rock formation, the hydrothermal phase, happens. Baryte- and fluorite corridors, Calcite, as well as ore deposits of gold, silver, copper, Galenite, Sphalerite, Pyrites and ores of Antimony und Arson are formed.

It is not only through contact metamorphism that already existing rocks can be altered; motion processes within the earth crust can also cause renewal through the so-called kinetic metamorphosis. Through bending of mountains, rocks can again arrive at great depths, where they
are subjected to much higher temperatures and pressures. With large-scale forces of high pressures and temperatures, particularly in areas of mountain formation and tectonic deformations, the so-called regional metamorphism takes place. Regional metamorphic rocks like crystalline schists are formed.

Accordingly, metamorphic rocks (Greek: „metamorphóo“ = restructure) are formed through the change of minerals and the structure of all rocks. In case of formation from magmatic rocks they are called ortho-rocks and in case of formation from sediment rocks they are called para-rocks.

At the earth’s surface all rocks are subject to disintegration, which is the condition of mechanical and chemical decay. The hardening of detritus products, gravel, clays, sands etc. is called diagenesis. So-called sediment rocks are formed, for example sandstone, limestone, claystone.

The economically utilizable mineral raw materials are most often present at the location of their formation as primary deposits. It is possible that a primary deposit is destroyed through weathering and the decomposition product is lead away through erosion of wind, water and ice. When the transport force subsides, the specific heavy products sediment, i.e. they are sorted based on the size of their grains and their specific weight. This often occurs at the inside of the curve of a river course (meander) or in the area of a river delta, at the entrance of the river to the sea. In this manner the secondary deposits in form of alluvial placers are formed, which provide the major part of the global production of gemstones, precious metals and heavy minerals.

At other locations the secondary sediments consolidate in very long periods through precipitate to solid rocks. After this diagenesis of the sedimentation rocks, the cycle of weathering, erosion and sedimentation can start anew and end in formation of tertiary deposits. E.g. along the African west coast there are extensive tertiary Diamond deposits in the sea.
Rocks are usually multi-grained mineral aggregates, which occur in independent, coherent compounds, which can be illustrated in geological maps and profiles. In this connection the concept “independent” means that the rock is the result of a definable geological process. Contrary to minerals, rocks are heterogenic natural compounds.

The content of minerals and the structure determine the rock type, its characteristics and technical specific values. The structure characterizes the formation and arrangement of the minerals in the rock, like for example mosaic structure in plutonic rocks, porphyric structure in volcanic rocks, agglomeration structure in sedimentary rocks or parallel structure in metamorphic rocks.

The following tables give an overview of some rock types and their assignment based on their genesis (genetic system).
Classification of the deposits according to utilization of the raw material

Energy raw materials

All natural raw materials that are used for the production of heat or electricity are called energy feedstock. Fundamentally renewable energies and energies from mineral raw material (fossil fuels) have to be differentiated. Renewable energies are for example water power, wind energy, solar energy, geothermal energy and biomasses like for example wood. Mineral fuels are hard coal and lignite, crude oil, natural gas, uranium, as well as oil sands and oil schist.

These so-called primary energies are mostly transformed into secondary energies through conversion processes, like for example electricity, district heating, petrol or fuel oil, and as such are made accessible to the society. The most important primary fuels are briefly introduced in the following section.

The so-called hard coal unit (SKE) was defined, in order to convert particular energies. The hard coal unit is the reference unit for the energetic assessment of various fuels. One kg of hard coal unit (kg SKE) corresponds to a value which is determined with 7,000 kilocalories (7,000 kcal = 29.3 MJ = 8,141 kWh) and as such corresponds to the calorific value of hard coal, which lies at approximately 29.3 MJ/kg (Gas flame coal) up to 33.5 MJ/kg (Anthracite), depending on the sort. Table 1-1 shows various fuels, as well as their energetic assessment.

LIGNITE- AND HARD COAL

Coal is formed through a conversion process, which is called coalification. Organic material in form of wood and leaves, which sunk into lakes and swamps, was secluded from air oxygen under suitable conditions. Under these conditions a conventional decay could not take place. Instead this organic material turns into turf over time.

Over geological periods sands, clay and rocks are deposited over this turf. Due to the pressure, which rises with the increasing covering and the increasing temperature, the coalification process starts, during the course of which the turf turns into lignite over 65 mission years and eventually turns into hard coal (355 million years). With an incremental duration of the coalification the carbon content in the coal deposit increases and the fuel value rises. In anthracite, an extremely hard coal, the share of carbon is 98 percent.

The most important coal deposits are found in temperate latitudes with a focus in the United States, Central and Eastern Europe, as well as China. In addition, there are three important mining regions in South Africa, India and Australia.

Fig. 2/3: Lignite- and Hard Coal are called primary energies and normally build seam layered deposits.
MINERAL OIL
For the formation of mineral oil it is necessary that animal and vegetal organisms sink to the ground of lakes and seas. The sunken organic residues are converted into a sapropel by animals. Under exclusion of oxygen this sapropel is gradually decomposed and covered by more sea sediments. Due to the increase in pressure and temperature, which is due to the covering by sediment layers, a gradual conversion into natural gas and the numerous components of mineral oil occurs. The mineral oil emigrated through pores and clefts from the bedrock into the surrounding rocks, until it was captured by an impermeable layer and was accumulated in the so-called bearing rock. The most important time period for the formation of mineral oil started around approximately 200 million years ago.

The mineral oil, which is extracted worldwide from various deposits, is utilized for production of fuels, lubricating and fuel oils, as well as utilized extensively for the chemical industry. The oil and gas reserves of the earth are distributed all over the globe.

Main locations of extraction are the areas at the Persian Gulf, Alaska, the southern states of the United States, Gulf of Mexico as well as Russia.

NATURAL GAS
Like mineral oil and coal, the natural gas is counted as organic raw material. The formation of natural gas is a natural process, which started millions of years ago and is continuing to the present. Like in the formation of mineral oil, basic materials are organic substances, like for example microorganisms, plankton and seaweeds. A fundamental condition of the subsequent formation of natural gas are areas, like for example coast regions, in which the above-average supply of organic substances has provided enough starting material. The organic material sank to the bottom of the sea and was converted under heretical sealing and covered by sediment layers. Due to the heretical sealing and the high pressure of the covering rock layers a lengthy chemical process was initiated, in the course of which organic substances were converted into gaseous hydrocarbons.

The natural gas which is extracted nowadays, was formed approximately 15 to 600 million years ago. The expression natural gas, in general covers all flammable hydrocarbon bonds, which stem from the earth. The chemical composition of natural gas can considerably fluctuate, however the main component is always methane (CH₄).

URANIUM
Uranium ore is the basis for power generation in nuclear power plants. Uranium is not found in nature as pure metal, but in the form of uranium minerals. The most important minerals in deposits are pitchblende (Uraninit, UO₂) and Coffinit (USiO₄). Altogether around 200 uranium minerals can be found in nature. The largest deposits are located in Australia, Kazakhstan, Canada, South Africa, Brazil, Namibia, Russia and the United States. However, around three quarters of the mined uranium stem from Canada.

A detailed report about Uranium Deposits you can read in the second part of the category „education“ on page 16.

Fig. 4: Uranium-Detoxit Rössing, Namibia
Metals account for the biggest group of chemical elements. Approximately 80% of all known elements are metals. It is for this reason that there are manifold metallic commodities extracted in mining.

Iron (Fe), which is used for the production of steel, and the steel refiners needed for this purpose like chromium (Cr), molybdenum (Mo), manganese (Mn), wolfram (W), nickel (Ni) and vanadium (V) belong to the metallic commodities. Precious metals like gold (Au), silver (Ag), platinum (Pt) or palladium (Pd) are also of high importance. But it is also impossible to imagine our society without the nonferrous metals like copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), mercury (Hg) or tin (Sn). Further metals like for example aluminum (Al) or titan (Ti) come along with that.

Metals are characterized by high electrical and thermic conductivity, the typical metallic gloss, easy formability, as well as usually high melting points. Many metals are important basic material and the functioning of a modern society would be impossible without them. It is not without reason that phases of human development have been called after the material used in that periods, like stone age, bronze age and iron age. An enriched occurrence in an accessible deposit is decisive for the mining of metallic commodities. The metals are mostly found in form of their oxides, sulfides, carbonates, halogenides or silicates.

Following some selected metallic ores are described.

**IRON ORE**

Iron ore has been used by man for more than 6,000 years. Today there is almost no area, in which we can do without iron or steel, whether in the domestic appliance industry, in the construction industry, in machine and plant construction or in the automobile industry.

Iron is an essential component of the earth. Together with nickel, it is probably the main component of the earth’s core, and as such jointly responsible for the formation of the earth’s magnetic field. Approximately 5% of the earth’s crust consists of iron in form of deposits that contain up to 60% of iron. Hematite, which is largely composed of Fe2O3, is the mineral, which is found most often. The big iron ore deposits are located in South America, mostly in Brazil, and in the west of Australia, in the People’s Republic of China and in Canada.

Technically iron is most important for the production of steel. Steels are alloys, which in addition to iron contain other metals and non-metals that add the desired characteristics to steel. The mined raw metal contains 3.5 to 4.5% carbon; therefore it is brittle and immediately softens when heated. The carbon content must be reduced, in order to transfer it to formable iron, i.e in order to produce steel.

Looking at the weight of the globally used metallic commodities, iron has a share of 95%.

**ALUMINIUM**

The element aluminum was discovered in the year 1825 by the Dane Hans Christian Oersted (1777-1851) while analyzing alaun. Therefore its name is derived from the Latin “alumen” (Alaun). Pure aluminum was first produced in the year 1827 by Friedrich Wöhler (1800-1882), through the reaction of aluminum chloride with potassium.

The aluminum ore which is mostly found in nature is Bauxite (Aluminiumhydroxide Al2O3). Bauxite develops as a weathering product from argillaceous lime-silicate and is named after the southern French city Les Baux. Famous deposits are in Australia, Guinea, Brazil France, Spain, Greece, Hungary, Rumania, Japan, Russia and North China. The deposits are mostly mined in open pits. Bauxite is an important raw material for the production of aluminum and fire-proof bricks.

Aluminum is a raw material that can be used in many ways. Due to its low density it is used in instances, where masses have to be moved, mainly in the packaging industry, the automobile industry, as well as in aerospace industry. In alloys with magnesium, silicium and other metals aluminum reaches a strength that can be compared to steel.
COPPER

Copper was one of the first metals used by man, since it often occurs in massive form and therefore does not have to be complexly smelted. This is the reason why it was used for weapons, ornaments or tools at a very early stage of our civilization. The developing ability, to alloy copper with tin gave its name to a whole human age – the bronze age.

Pure copper is used in electric cables and conductors, as well as in heat conductors, due to its very good conductivity. The covering of roofs with copper sheets is also typical, since the sheets develop a durable greenish patina (vergriss), which again protects the underlying material from further corrosion. It is for this reason that copper roofs can have a durability of several hundreds of years. Furthermore copper is the component of many alloys, such as brass ore bronze. Copper compounds are applied in colour pigments, medical preparations and galvanic surface coatings.

Copper deposits are very often found in sulphured forms. Oxidic copper mineral deposits are formed secondary through weathering processes. The copper mineral with the widest incidence is Chalcopyrite (CuFeS₂). Most of the copper deposits are mined in open pits; it is only in case of copper ores with a very high concentration that underground mining is worthwhile. The most important copper deposits are located in Chile, Indonesia, The United States, Russia, Australia, Peru and in southern Africa.

GOLD

Gold has been one of the first metals processed by man. The reason for this fact is on one hand its striking yellow colour, one the other hand because gold is found very often in massive form, and consequently does not have to be extracted from ores. Gold is probably the most important metal globally. It is the most expandable of all metals, and it is possible to produce a 3 km long wire from one gram of Gold. This characteristic is also taken advantage of in the production of gold foils. The metal can be rolled out to a thickness of approximately 1 micrometer and as such can be used for various artistic purposes.

The mineable deposits are distributed all over the world however they are concentrated in some countries. Around 40 percent of the mined gold ore comes from Australia, the United States and South Africa.

Due to the advancement in the excavation and processing techniques, today it is possible to economically mine sources, which only contain a few grams of gold per ton of rock. Furthermore considerable amounts of gold are obtained during extraction and refining of other metals, such as copper, nickel and other precious metals. Partly it is these additional components that make such a deposit economically productive.

Gold is used in forms of gold coins and bar gold as international means of payment, although nowadays the stability of a currency does not rely on backing by gold reserves. A further utilization of gold is in the jewelry industry.

Due to its corrosion resistance and its aesthetic qualities, gold is also used in dentistry. The electronic industry uses gold for the same reasons, because of the reliability of its characteristics, the corrosion resistance and the good processability.

Aggregates

Aggregates are important mineral raw materials, without which construction of buildings, roads and other infrastructural facilities would be unthinkable. In the following sections some aggregates, their genesis and their usage are examined more closely.

LIMESTONE

Limestone deposits were formed millions of years ago, as a result of organogen and chemical processes in the sea. Lime sludge that sedimented to the bottom of the sea hardened, was compacted through the load of younger sediments and was transformed into compact rock in the course of millions of years. Partially a reaction of the limestone with magnesium containing waters happened and lead to formation of dolomites, which is closely related to limestone. E.g. the limestone deposits of Germany are up to 600 million years old. Alliances of clay, limestone and partly sand are called marl. Based on its components the stones are called clay marl (10 to 30% CaCO₃), lime marl (30 to 85% CaCO₃) or marly lime (85 to 95% CaCO₃).

A major part of the limestone and dolomite production is used in the lime industry. Products of the lime industry are divided into burnt and unburnt products. Unburnt products are products which are sold after being extracted in quarries, crushed and screened.

In order to produce burnt products, they have to undergo a burning process, in which CaCO₃ is transformed into CaO und CO₂ in a chemical process. All products of quicklime and lime hydrate, as well as hydraulic limes are counted as burnt lime products. Approximately 1.8 tons of limestone is needed for the production of one ton of quicklime.

The oldest field of application of lime is the construction business. For thousands of years lime has been used for mixing of mortar in construction sites.

 Crushed limestone and limestone that is processed to gravel, split or crushed stone fines is added to concrete. This limestone concrete is used as bulk concrete in large constructions like dams or bridges, due its minor dilatation. The minor dilatation during heat generation leads to an increased usage of limestone addition in places, where concrete is subjected to high temperatures.

EA further field of application of limestone is the lime sand brick industry. Lime sand bricks, which are produced by a mixture of fine lime, sand and water, are an
important material in housing construction. As such every third brick used in the Federal Republic of Germany is a lime sand brick. An alternative to the lime sand brick is porous concrete, being mixed of quartz sand, lime, concrete and water. Through an addition of aluminum powder the mixture can be frothed up and it develops excellent characteristics for heat retention, while at the same time having a very low weight.

Limestone is also of importance for the production of cement, which is one of the most important binding agents worldwide. Cement is produced from the raw materials limestone, clay, sand and iron ore. For the production of one ton of cement barely 1.4 tons of limestone is used.

A further application area of lime, limestone and dolomites is the road construction business. Limestone is used in all layers of the road construction, from the anti-freeze layer to the asphalt covering layer.

Lime and limestone are applied in the production of steel in various forms and in large amounts. For the production of one ton of raw iron, approximately 100 to 200 kg of limestone are being used. The limestone, which is being added in the blast furnace, contributes to a better slagging.

Lime is suitable for an application in the area of improvement and hardening of soil. Thereby lime extracts water from the soil, so that the load bearing capacity is improved and the soil becomes frost resistant. Furthermore lime is an important soil nutrient. A balanced condition with regard to the lime content of an agriculturally used soil influences the fertility and consequently the agricultural earning. Farmland looses its fertility in the course of time, due to the fact that on one hand the nutrient CaO is washed out through rainfall, and on the other hand the plants themselves extract the nutrient CaO during their growth. Therefore it is essential to regularly lime the soil, in order to maintain its productivity.

Already hundreds of years ago, the chemical industry used lime as a particularly inexpensive base for the production of inorganic and organic calcium alliances. Furthermore lime is used for changing pH values, as reactants in chemical synthesis, in physical and chemical preparation processes and for neutralization. For example lime and lime stone is used for the production of citric acid, adhesives, paint, pharmaceuticals, varnish, lime soap for the paper industry, propylene oxide for softeners in the synthetics industry, as well as gloss pigments.

SAND AND GRAVEL

Sand and gravel are the most important mineral commodities both globally and in the Federal Republic of Germany. Loose aggregates with a diameter of around 0.1 to 2 mm are called sands. For gravels the diameter is between 2 to 63 mm.

Hereby the demand can be met by local deposits. As such in Germany over one million tons of sand and gravel are mined, transported and processed every working day. A differentiation has to be made between sand and gravel, which are used as construction material, and special sands and gravels.

Sand and gravel are important raw materials for a multitude of industry branches. Particularly the construction industry is dependent upon a sufficient supply of sand and gravel. Therefore the sand and gravel industry contributes significantly to a smooth supply of this important branch of the economy.

The various consumers are considerably dependant upon the availability of nearby produced sand and gravel, since in case of long distances, the transport costs for these mass commodities easily exceed the costs for extraction and processing by a multiple.

Fig. 6: Limestone Deposit, Union Bridge Quarry, USA
Mining of sand and gravel deposits can be done both as dry and as wet extraction. In dry extraction the deposit is exploited above the ground water, in wet extraction this is done below the ground water. Two thirds of the excavation areas are mined with wet extraction in central Europe. The so-called raw gravel is extracted, and is subsequently washed and screened.

Products that are produced using sand and gravel, are for instance concrete (consisting of around 80% of sand and gravel), concrete components, paving stones, sewage pipes, railway sleepers and building bricks. Furthermore sand is used in road construction for the production of asphalt and concrete, as well as for the production of anti-freeze and base layers.

Approximately 95% of the extracted sand and gravels are being used in the construction industry. High quality special sands and gravels with special quality requirements have a share of close to 5%, particularly in the glass and ceramics industry, in the iron producing and iron processing industry, as well as in the chemical industry.

**Fig. 7/8: Gravel- and Sand - Deposit, Germany**

*top: Dry mining, below: Wet mining*

**NATURAL STONE**

The natural stone industry consists of extraction operations of natural stone (quarries) for civil engineering, processing plants which are often connected to further processing plants (asphalt plants, concrete plants, as well as concrete and prefabricated part plants). As for the importance of these industries regarding the supply of the construction industry with raw materials, it is the same as mentioned for sand and gravel.

Natural stone with a grain size of up to 0.125 mm is called filler, up to 4 and 5 mm respectively it is called crushed sand, up to 32 mm split and above 32 mm it is called rubble. These grainings are used for around 75% in all layers of the road and underground construction, either unbound, or bound hydraulically or bituminously. As an example they are used as roadbed and fill material, as anti freeze or base course, as well as as binder and coating layer. As an example for 100 m of highway 2,600 tons of crushed natural stone is needed. This makes the road stable and slip proof.

Approximately 20% of the natural stone are used as split in concrete production for bridges, stadiums, dams and many others. The rest is being used as track ballast in the construction of railroads or as water building blocks for the stabilization of rivers and shore line stabilization.

**Fig. 9: Basalt Deposit with typical pillar structure, Germany**
DIMENSION STONE / ASHLAR

Dimension Stone has been used from prehistoric times and has been the predominant construction material for centuries. In particular representative historic construction projects like the Egyptian pyramids, the Greek temple complexes and the Gothic cathedrals, as well as the baroque castle complexes were constructed from ashlar. Sandstone, marble, granite or slate are used for dimension stone.

The usage of ashlar was strongly limited after the development of cheaper construction material like concrete and lime sand brick. Currently this construction material is mainly used as flooring and wall covering.

Ashlar stands out by its specific rock characteristics. As such, various work pieces are made from ashlar, such as structure sheathing, bottom plates, monuments or base bodies for stonemason and stone carver works. Ashlar is usually not blasted, but mechanically loosened or sawed out of the rock unit, so that the desired characteristics of the raw blocks which are loosened from the deposit corresponds to the requirements. Despite the fact that ashlar deposits are widespread, suitable sources for extraction of free stone are extremely rare and consequently particularly valuable.

An important ashlar, which is multifacetedly applied in the construction industry, is schist. In the course of millions of years sedimented and most fine clay sludge was transformed into metamorphic schist, due to the influence of high temperatures and pressures. The typical schist structure is formed through a sequence of mica layers, which contributes to a good divisibility and to being weather-resistant, which is very much in demand. Schist has been used as construction material for over 2,000 years. Although Schist has been used in the middle-ages for roof covering, but lost its importance later, only to experience a boom in the last 25 years. This was made possible because modern schist mines were able to produce schist at a price that made a mass production of this natural stone possible. In Germany approximately five million square meters of schist roof are being produced annually.

CLAY AND LOAM

Loam is a mixture of clay, silt and sand, which can contain additions of pebbly stone particles, as well as organic material. The clay in the mud serves as binding agent. Clay and loam have been used as construction material for a long time, as they are well formable in wet condition and dry to hard bodies.

Nowadays the major part of the clay and loam production is used for the production of various bricks (clay bricks, clinker, roof and ceiling tiles) and fireproof products. Clays are used for products in the ceramics industry, as well as for construction material and smelters. Sales markets are, among others, sanitary ware, sewerage pipes industry, the production of technical ceramics, the fire-proof and acid-proof industry, the plastic industry, as well as the rubber and feeding stuff industry. Kaolin or kaolinitic clays are used in paper, ceramic and fire-proof industry, as filler material in the production of paint, varnish, rubber and plastics, as ceramic substrates in exhaust catalysts, as well as in sealing material for dumpsites.

Fireproof products are needed for all industrial processes, which go along with high temperatures. Without the manufactured special products neither steel, nor glass, aluminum, copper, lime or concrete can be produced. Therefore the fire-proof industry enjoys an indispensable key position, although it is not a big branch of the industry.

The raw material clay is not only processed in Germany, but in demand in all of Europe, which is proven by the high export share. Particularly German fire-proof products are globally leading. Here the export share lies at approximately 50%.

Fig. 10: Marble Deposit, Carrara, Italy. Production of Dimension Stones
Salt and industrial minerals

Rock salt (sodium chloride, NaCl) is found in large salt deposits, which were formed around 240 million years ago through the evaporation of earlier salt lakes or bays. Rock salt is extracted through underground mining in salt mines or through salt solution in caverns.

Salt, as one of the first and most precious merchandises is still of great economic importance. Rock salt in the form of table salt is being used in the food industry and in households. Another important area of application is the usage of road and de-icing salt in winter. De-icing salt is the most effective and most economical means to keep roads and highways free of snow and ice. Today salt is an indispensable commodity, particularly for the chemical industry, for instance for the production of soda, chlorine and sodium hydroxide. Without the basic agent salt it would be impossible to produce glass, plastics or aluminum. Furthermore salt plays an important role in the production of textiles, paper, detergents, pharmaceutics, as well as paint.

The second important salt is potassium salt, which is a mixture of potassium chloride and potassium sulfate with magnesium and calcium alliances and which is mainly used as fertilizer.

Sulphur, heavy spar and calcium fluoride are counted as industrial minerals.

The biggest share of the worldwide sulphur production is from sulphur which is extracted from sulphur ore. Around 50 million tons per year come from this source. Furthermore large amounts of sulphur develop during the desulphurization of natural gas. Application areas of sulphur are found both in the chemical, as well as in the pharmaceutical industry, here primarily for the production of sulphuric acid, dye, insecticides and chemical fertilizers. Sulphur is also used in the production of gunpowder and other explosives.

Barite is another name for Bariumsulphate (BaSO₄). The rock, which is also called Barite, is used as an additive to drilling fluids, due to its high density. Due to the high density a high gravitational pressure can be achieved in the fluid. Furthermore Barite is used as white pigment, for the production of heavy concrete, as contrast medium in x-ray examinations and for the extraction of barium.
There is a very wide geological variety of uranium deposits. The currently most important mineralization styles are unconformity-related Proterozoic deposits (mainly in Canada and Australia), roll-front deposits in Mesozoic-Cenozoic sandstone (Kazakhstan and USA), and IOCG (“Iron Oxide-Copper-Gold”) deposits in hematitic granite breccias where uranium is a by-product of copper mining (Olympic Dam, Australia). The uranium deposit spectrum is controlled by the high aqueous solubility of uranium in the hexavalent state, and low solubility in the tetravalent state. This geochemical background is reflected in large-scale leaching of uranium by oxidized meteoric or formation waters, and precipitation of uraninite (UO$_2$) at redox fronts. Evapotranspiration under arid climate conditions can lead to uranium enrichment in near-surface calcrete deposits (Namibia and Australia). Paleoplacers (quartz-pebble conglomerates), restricted to Late Archean to Early Proterozoic age, contain a large low-grade resource of clastic uraninite (South Africa, Canada). The currently known uranium resources are sufficient to sustain current and future nuclear power generation for the next 100 years. Advanced fast neutron technologies would extend the resource life time to more than 1000 years.

Introduction

Uranium is essentially used for electricity generation in nuclear reactors, after a first period from 1945-1960 when military demand for nuclear bombs was prevailing. Civilian nuclear power started in the 1960s, with strong growth during 25 years, but levelled out after the Chernobyl accident in the Soviet Union in 1986. About 35 % of the European Union’s electricity are produced from nuclear energy today, but no new reactors were built since twenty years. There is currently renewed interest because nuclear energy is neutral in terms of its greenhouse effect and is capable of generating large amounts of power at low cost compared to rival non-nuclear energies. AREVA, the French world nuclear energy leader, is currently constructing two third-generation nuclear reactors in China, and another one in Finland, known as „European Pressurised Water Reactor” (EPR). And there are projects in the major industrialized countries to develop fourth-generation fast neutron nuclear reactors which will have an efficiency many times superior to the current technology.
Such nuclear energy systems are set to play a key role in a sustainable long-term world energy balance.

There is currently a boom in uranium exploration, with a global expenditure of about 720 million USD in 2007 for exploration and mine development (Fig. 1), still much below the exploration budgets in the late 1970s.

Natural uranium consists essentially of two isotopes, $^{238}\text{U}$ with an abundance of 99.3 % and $^{235}\text{U}$ with an abundance of 0.7 % which slowly decay to $^{206}\text{Pb}$ and $^{207}\text{Pb}$, respectively ($T_{\text{1/2}}^{238}\text{U} = 4.5 \text{ Ga}; T_{\text{1/2}}^{235}\text{U} = 710 \text{ Ma}$). Only $^{235}\text{U}$ can be used in conventional fission reactors, and most reactors (Light Water Reactors) use enriched uranium where the proportion of the $^{235}\text{U}$ isotope has been increased from the present-day natural composition at 0.7 % to about 3 % or up to 5 % (for comparison, uranium used for nuclear weapons has to be enriched to at least 90 % $^{235}\text{U}$). The world consumption of uranium (non-enriched) for the total of 439 operating reactors (September 2008) is about 65,000 t U per year from which 2600 TWh (1 TWh = 1 billion kWh) electricity are generated, equivalent of 16 % of total world electricity generation.

The mine production of uranium in 2007 is shown in Figure 2, with Canada (23 %), Australia (21 %) and Kazakhstan (16 %) standing out. Germany contributed 0.1 % from treatment of mine waters from former uranium mining areas in eastern Germany. Historically, eastern Germany and the Czech Republic during the times of the GDR and Czechoslovakia, respectively, were significant providers for the Soviet nuclear arsenal. There is a difference between uranium demand (65,000 t/yr) and mine production (41,300 t/yr) which is covered from the large military inventories of the USA and Russia, and from recycling of nuclear waste (Fig. 3).

The currently identified uranium resources are adequate to meet the requirements during the lifetime of the current nuclear plants, as well as an expansion of up to 80 % expected by 2030, although supply shortfalls could develop given the long lead time typically required to bring new resources into production, and given the long period of stagnation of the uranium market at very low uranium prices in the recent past, which were insufficient to sustain investment in exploration and development. Deployment of advanced reactor and fuel cycle technology could extend the long-term availability of nuclear energy from a century to thousands of years. Such technology would use fast neutrons which are able to fission $^{238}\text{U}$, and therefore use the other 99.3 % of natural uranium which are currently wasted or stockpiled.
Uranium was discovered in pitchblende ore from Johanngeorgenstadt in the Erzgebirge by the Berlin pharmacist Klaproth in 1789, and only gained wider interest 150 years later, when Hahn and Strassmann, again in Berlin, discovered nuclear fission of $^{235}$U in 1938. This process liberates more neutrons than it consumes which allows a chain reaction provided a critical mass of several kg $^{235}$U is assembled. It then took only four years to construct the first nuclear reactor in Chicago, and another three years to test the first atomic bomb in Nevada, and to destroy the cities of Hiroshima and Nagasaki with a uranium (60 kg $^{235}$U) and a plutonium (8 kg $^{239}$Pu) bomb, respectively. This development started a frantic and very costly arms race of about 30 years in which several countries tested and developed a wide range of nuclear technology and stockpiled thousands of nuclear warheads, part of which are now reconverted for fuel in power plants. Ironically, half of the US commercial reactor fuel today is from Russian nuclear warheads.

Geochemical background

The upper 10 km of the Earth’s continental crust have an average abundance of 2.7 g/t U (Rudnick & Gao 2003). The grade of uranium ore deposits ranges from a few hundred g/t U to more than 20 % U. Therefore, an ore-forming process is required which enriches uranium over its global geochemical background by a factor of 100 to 10,000. Such enrichment is possible by leaching of large rock volumes by oxidized warm water and precipitation of uranium (commonly in the form of uraninite, $\text{UO}_2$, also known as pitchblende, due to its black color) in such places where the solubility of uranium changes. Uranium exists in two oxidation states. Uranium in the 6$^+$ state is highly soluble, while uranium in the 4$^+$ state is highly insoluble. This can be condensed into the general geochemical formulation:

$$\begin{align*}
\text{U}^{6+} (\text{aqueous}) + 2 \text{e}^- &= \text{U}^{4+} (\text{precipitation}) \\
\text{Or, in a natural system,} \\
\text{UO}_2(\text{CO}_3)_2^{2-} + 2 \text{H}^+ &= \text{UO}_2 + \frac{1}{2} \text{O}_2 + 2 \text{CO}_2 + \text{H}_2\text{O} \\
(1)
\end{align*}$$

Note that there are many other possible uranium complexes in nature, but the underlying theme is the dissolved U species in the 6$^+$ state, while the precipitated U species is in the 4$^+$ state. The solubility of $\text{U}^{6+}$ at low temperatures is extremely low, similar to thorium as $\text{Th}^{4+}$.

However, thorium, as opposed to uranium, has no oxidized species which is why it is not enriched in low-temperature hydrothermal deposits. Only under high-temperature conditions, particularly in silicate melts, uranium and thorium can become enriched synchronously due to their common large ionic radius and high charge and then can form U-Th deposits in pegmatites and alkaline granites.

Equation (1) describes sufficiently both the formation of hydrothermal uranium ore deposits (reaction from the left to the right side), as well as their mining by in-situ solution techniques (reaction from right to left).

The solubility of uranium as described in (1) can then be formulated as

$$\begin{align*}
\log K &= \log [\text{UO}_2(\text{CO}_3)_2^{2-}] + 2 \log [\text{H}^+] - \frac{1}{2} \log [\text{O}_2] - 2 \log [\text{CO}_2] \\
\log [\text{UO}_2(\text{CO}_3)_2^{2-}] &= \log K + 2 \text{pH} + \frac{1}{2} \log [\text{O}_2] + 2 \log [\text{CO}_2]
\end{align*}$$

This equation describes the solubility of uranium as a function of pH, oxidation state, and CO$_2$ fugacity. Given a situation where pH is buffered by rocks, the solubility of uranium will be controlled by the concentration of CO$_2$ and O$_2$ in the solution. A practical example for this relationship is given in Figure 4, where the change from an oxidized environment with U soluble to a reduced environment with U insoluble can be read directly from the rock. Uranium ore formation by precipitation as uraninite from oxidized solutions marks the transition from oxidized to reduced environments.

![Fig. 3: Uranium mine production and civilian demand since 1945. Note the difference between demand and mine production since the 1990s which is mainly covered by recycled uranium from military inventories. (Source: Nuclear Energy Agency 2008).](image-url)
In-situ solution mining reverses this process by forcing an oxidized environment on the reduced uranium ore deposit whereby uraninite is dissolved.

Hydrothermal mobility of uranium requires an oxidized environment of fluid circulation. Note that the term „hydrothermal“ refers to any kind of warm water, without a genetic connotation. Oxidized conditions exist only since about 2.4 Ga when the Earth’s atmosphere first developed oxygen levels in the percent range. There are no hydrothermal uranium deposits prior to this period, but there are magmatic enrichments of uranium in granites and granite pegmatites throughout the history of Earth. Uranium behaves as an incompatible element in felsic melt systems, i.e. is not incorporated into the major silicate minerals, and becomes enriched in residual melts. Prior to 2.4 Ga, uraninite with high thorium content from erosion of such rocks was an insoluble heavy mineral and became enriched in fluvial placers, such as the Witwatersrand, South Africa, or Blind River/Elliott Lake district, Canada. Such uranium placers only formed in the Archean oxygen-free environment. Under recent atmospheric conditions, uraninite dissolves easily in rain water, and the erosion of uranium deposits, or even uranium-rich granites (10-20 g/t U), produces broad secondary dispersion halos which are used for finding uranium ore. The high solubility of uranium under oxidizing conditions even at low temperatures allows enrichment under arid to semi-arid weathering conditions where uranium can be precipitated due to evapotranspiration. In this environment, hexavalent uranium is fixed commonly together with potassium and vanadium, and then forms a number of deep yellow to green minerals such as carnotite \(K_2(UO_2)V_2O_8 \cdot 3H_2O\) and tyuyamunite \(Ca(UO_2)V_2O_8 \cdot 5-8½ H_2O\) (Fig. 5). The predominance of uranium vanadates in these deposits is due to the low solubility of U-V compounds compared to all other \((UO_2)^{2+}\) minerals.

Uranium is variably enriched in igneous rocks due to its large ionic size and charge which does not allow incorporation of uranium into the major rock-forming minerals during crystallization. Uranium is similar in its physicochemical properties to thorium, and both elements become enriched in residual melts during crystal fractionation. Particularly granitic rocks are enriched in both elements and provide a reservoir for leaching by warm water. However, thorium is much less soluble than uranium which is why hydrothermal uranium deposits have low Th contents. There are also igneous rocks which are so highly fractionated that uranium (and thorium) reach ore grade, i.e. a few hundred g/t. Such rocks are pegmatites and leucogranites, as well as highly alkaline rocks.

**Major uranium deposit types**

Uranium deposits form in a very wide range of geological environments. Historically, vein-type deposits were the most important, as well as paleoplacers. These mineralization styles tend to be relatively low grade (commonly < 1 % U), and the discovery of high-grade unconformity-
related deposits in Canada during the 1960s, and of very-high-grade deposits up to around 20 % U in the same setting in the 1980s changed the economics of uranium. Nevertheless, there are currently still many low-grade and very-low grade (< 0.05 % U) deposits profitably mined, either due to cheap extraction techniques (such as in-situ leaching) or due to co-production of copper and gold (such as in IOCG deposits). Figure 6 gives an overview of the more important mineralization styles in terms of tonnage and grade. The high end in terms of grade is represented by unconformity-related deposits, the low end by paleoplacers and the giant Olympic Dam IOCG deposit in Australia.

Three major types of hydrothermal uranium ore deposits provide about 85 % of the present-day world uranium mine production. These are (1) unconformity-related uranium deposits, (2) sandstone-hosted or „roll front“ deposits, and (3) IOCG („Iron Oxide-Copper-Gold) deposits. All three types form at redox fronts where oxidized basinal brines or meteoric water meet reducing lithologies or methane-bearing fluids. The basic process is large-scale leaching of U⁶⁺ from average or slightly uranium-enriched rocks under oxidizing conditions, and fixation in the U⁴⁺ state (uraninite; UO₂). This ore formation requires large amounts of oxidized warm water, such as available in intracratonic basins with km-thick sequences of red sandstone (+gypsum).

Large-scale fluid circulation can leach both the sedimentary basin sequence as well as the underlying metamorphic basement.

The reduction can be achieved by interaction of such water with reduced lithologies (for instance, graphite schist) or with hydrocarbons. The textbook example for this situation is the Athabasca basin in northern Saskatchewan, Canada, where several large mines work (or are developed to mine) ore with up to 20 % U (McArthur River, Cigar Lake) (Fig. 7 and 8).

These high-grade deposits occur near the unconformity of the Archean to Paleoproterozoic metamorphic basement and the overlying 1.9 Ga-old Athabasca sandstone, and are therefore commonly termed unconformity-related uranium deposits. The uranium mineralization is spatially associated with sheared graphite-bearing meta-sedimentary units in the basement, which have transmitted their reduced environment via hydrothermal halos into the overlying sandstone (Fig. 9). This control is important for exploration of hidden ore bodies by electrical geophysical methods.

A similar example are the classical sandstone or roll-front deposits in the western USA where uranium is concentrated in sandstone aquifers where the lithology changes from oxidized to reduced (Fig. 10).

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**Fig. 6:** Grade versus tonnage plot of major uranium deposits. Data form many sources. Note that pre-mining data vary depending on economic and geological assumptions. Geographic allocation of the deposits identified by name: Canada (McArthur River, Cigar Lake, Collins Bay, Key Lake, Midwest. McClean Lake, Quirke Lake), Australia (Nabarlek, Ranger, Jabiluka, Yeelirrie, Olympic Dam), Congo (Shinkolobwe), Czech Republic (Pribram, Rozna), Germany (Aue/Niederschlema, Zobes, Ronneburg, Menzenschwand), France (Fanay), Russia (Streltsov), Kazakhstan (Mynkuduk, Inkai), Namibia (Langer Heinrich, Rössing), South Africa (Welkom, West Rand).
Fig. 7: Unconformity-related uranium ore in the Athabasca sandstone: Drill core from the Pod 2 area of the McArthur River deposit, Saskatchewan, Canada. DDH 301 consists over several meters of very-high-grade (> 50 % U) friable uraninite and argillic minerals. (Photo: Lehmann).

Fig. 8: Geological setting of the unconformity-type uranium deposits of the Athabasca Basin in Saskatchewan which has a current total resource of about 600,000 t U at an average grade of about 2 %. “MF” refers to the mid-Proterozoic Manitou Falls Formation which is the lower unit of the sedimentary Athabasca basin sequence. The major deposits are near the 200 km long southeastern border of the clastic sandstones and their Paleo-Proterozoic and Archean metamorphic basement. The major deposits are Key Lake (70,000 t U, 2 %, mined out), McArthur River (proven 80,000 t U, 15 %, + probable 62,600 t U, 22 %, active mining), Cigar Lake (87,000 t U, 21 % U, in development). From Jefferson et al. (2007: 276).
The reducing environment is here commonly induced by organic components or sedimentary-diagenetic pyrite in the sandstone. An even more effective means of reduction can be provided by oil or gas (methane), given the right hydraulic gradients. Such a situation seems to be given in central Kazakhstan, where many small to intermediate size uranium deposits in Late Cretaceous to Tertiary sandstone form a giant uranium province which is associated with gas fields in the same area. These deposits are low-grade (~ 0.03 - 0.05 % U), but host a huge resource of about 1.1 Gt U and can easily be exploited by in-situ leach techniques because the unconsolidated sand and sandstone aquifers have a good permeability (Fig. 11).

Fig. 9:
Three examples of major unconformity-associated uranium deposits in the southeastern part of the Athabasca Basin.

(A) Cigar Lake (underground mine development) is mainly immediately above the unconformity in hydrothermally altered sandstone.

(B) Deilmann (open pit, mined out) at Key Lake is both basement-hosted and unconformity ore.

(C) Eagle Point is mostly basement-hosted (originally mined by open pit and underground; hanging-wall lenses still being developed and mined underground).

All mineralization styles are related to sheared graphite-bearing metasedimentary rock units in the basement. Vertical scale-horizontal scale. From Jefferson et al. (2007: 287).
The IOCG ("Iron oxide-Copper-Gold") deposit style is mainly known from the Gawler craton in southern Australia, with the supergiant Olympic Dam deposit standing out. The latest total resource figures make this deposit the largest uranium deposit known, although uranium is only a by-product of copper mining: 8.3 Gt @ 0.88 % Cu, 0.24 kg/t U, 0.31 g/t Au, 1.50 g/t Ag (BHP Billiton Annual Report 2008). Mining is currently still underground, but a multi-billion open-pit project with exceptional dimensions is underway. The Olympic Dam Cu-U-Au deposit consists of a huge Mesoproterozoic (~ 1590 Ma) granite breccia complex with abundant hematite (up to 90 %) and minor magnetite, as well as sulfides, and its formation is not well understood. This deposit has produced 3,500 t U in the past year (1 July 2007 to 30 June 2008, as to BHP Billiton reporting style), and is the only important uranium deposit of the IOCG style.

There is a variety of other uranium ore deposits of currently less economic importance. These cover all geological environments. The hydrothermal environment has classical vein type and shear-zone related deposits which were important in the early days of uranium mining. A large part of the European uranium production came from such veins systems in the Hercynian fold- and thrust-belts of the Bohemian Massif/Erzgebirge (Czech Republic and Germany) and the French Massif Central. An important part of the East German uranium production came from Early Paleozoic black shales in the Ronneburg district which picked up much uranium at a synsedimentary redox front ( euxinic environment) which then probably became upgraded on weathering. This deposit style is known from other regions, particularly from the Cambrian alum shale in Sweden, where the uranium grade around 0.1 % U is below current economic feasibility (Fig. 6).
Uraninite is a heavy mineral (density of 9.0 - 9.7 g/cm³) which can be enriched in placers under reducing conditions. Such conditions do not exist on the present-day Earth with a 20 % oxygen atmosphere. However, oxygen content in the atmosphere prior to about 2.4 Ga was very low (<< 1 % O₂), which allowed enrichment of uraninite and pyrite as a clastic heavy mineral in the exogene environment. There are huge uranium paleo-placers, also known as quartz-pebble meta-conglomerates, in the 3.1-2.7 Ga Witwatersrand basin of South African, and in the 2.45 Ga Blind River/Elliott Lake district in Ontario, Canada. The clastic uraninite has a high thorium content of several weight-percent which indicates an origin from granitic or pegmatitic sources. Part of the uranium component has reacted with bitumen to amorphous „thucho-lite“ (synthetic name from the Th-U-CHO association). Under the microscope, the uraninite pebbles display minute inclusions of galena, derived from radiogenic lead. This observation allowed a first ore microscopy-based age estimate of the mineralization, later refined by microanalytical isotope measurements.

Uranium is variably enriched in igneous rocks due to its large ionic size and charge which do not allow incorporation of uranium into the major rock-forming minerals during crystallization. Uranium is similar in its physicochemical properties to thorium, and both elements become enriched in residual melts during crystal fractionation. Particularly granitic rocks are enriched in both elements and provide a reservoir for leaching by warm water. However, thorium is much less soluble than uranium which is why hydrothermal uranium deposits have low Th contents. There are also igneous rocks which are so highly fractionated that uranium (and thorium) reach ore grade, i.e. a few hundred g/t. Such rocks are pegmatites and leucogranites, as well as highly alkaline rocks. The currently only example of an economic deposit of this type is the very large Rössing deposit in Namibia which produced about 3,000 t U in 2007 from low-cost open-pit production at a grade of about 300 g/t U.
Natural nuclear reactors

It is interesting to know that nuclear reactors are not only man made, but also occurred in nature in a specific time window when two conditions were met: (1) Enough oxygen was in the atmosphere to allow mobilization and transport of uranium by warm water, and local precipitation of uraninite, as today in high-grade unconformity- and sandstone-type U deposits; (2) The proportion of $^{235}$U in natural uranium was about ≥ 3.5 % which was realized at about 2 Ga and beyond, given the about six times shorter half-life of $^{235}$U compared to $^{238}$U. These two conditions bracket the natural formation of a critical mass of uranium at the time of about 2.0 - 2.4 Ga. Natural nuclear reactors were discovered in the 2 Ga Franceville basin in eastern Gabon in 1972 where 16 natural nuclear reactors are known so far. These reactors operated based on ore concentrations in sandstone of ≥ 20 % U with then 3.7 % $^{235}$U, and water acted as moderator to slow down high-energy neutrons to be able to be absorbed by $^{235}$U atoms and trigger fission. As the chain reaction proceeds, however, it generates heat which boils away the water, dries up the reactor and shuts it off. Similar to a geyser in a geothermal field, the process then starts up again after recharge by cold groundwater. Fissiogenic Xe and Kr trapped in alumino-phosphate minerals allows a detailed reconstruction of the life cycles of these reactors which operated over 150,000 years, with probably 30-min active pulses separated by 2.5-h dormant periods for water recharge (Meshik et al. 2004). The energy released during the life time of these reactors is estimated at ~15 GWyr, and about 50 % of this energy came from „breeding“, i.e. internal production of $^{239}$Pu from neutron capture of $^{238}$U, and α-decay of $^{239}$Pu to $^{235}$U. Even more astonishing, these open-system breeder reactors did not contaminate large areas, but their toxic and radiogenic components behaved essentially immobile over their 2 Ga history until today, due to the reducing and argillic nature of the country rocks. This natural analogon of a nuclear waste repository is relevant for the current discussion on safety of waste storage.

Fig. 13: Uranium distribution in the Earth’s crust. The bars represent various categories of uranium deposits (in blue) or geological repositories of uranium (in red). The currently mined uranium deposits have a very large grade range from a few hundred g/t to about 20 %. The arrows locate the grade at the extremes of this range, with the giant and low-grade Olympic Dam Cu-U-Au mine in Australia, and the very-high-grade unconformity-type U deposit of Cigar Lake in Canada (in development). Adapted from Deffeyes and MacGregor (1980).
Resource perspective

The resource distribution of uranium in the Earth’s crust is of more than passing interest, because nuclear reactors may become the preferred source of electricity generation in the future, once climate change and oil/gas shortages are widely perceived as particularly unpleasant. Figure 13 gives an overview on the availability of uranium in the Earth’s lithosphere and hydrosphere. The amount of uranium in the several types of uranium deposits increases progressively as the grade decreases. The data in Figure 13 show that at the present rate of mining the amount of uranium in ore with more than 0.1 % U will last more than 1000 years. Much of this amount is uneconomic at the current price. The uranium resources recoverable at a price of up to 130 USD/kg U are estimated at 5.5 Mt (NEA 2008).

Average seawater has an abundance of 3.2 ppb (ng/g) U, and there are about 4.5 Gt U in the form of uranyl-tricarbonate $[\text{UO}_2\text{(CO}_3\text{)}_3]^2-$ in the oceans which have a total mass of seawater of $1.4 \times 10^{18}$ t. Uranium extraction by adsorption has been experimentally tested, and seawater mining could be done powered by ocean currents. Industrial-scale production was, however, never tested and is estimated to become profitable at a price of about 400-1200 USD/kg U (Macfarlane & Miller 2007).

Economic perspective

The production cost of electric energy from nuclear power plants in 2005 was 1.7 US ct/kWh, compared to 2.2 US ct for coal, 7.5 ct for natural gas, and 8.1 ct for oil (operation, fuel and maintenance; US data in NEA 2008). Given that the cost of natural uranium constitutes only 3 - 5 % of the cost of a kilowatt-hour of nuclear-generated electricity, compared to 78 % for coal, 94 % for natural gas and 91 % for oil, large increases in the price of natural uranium have much less impact than price hikes for coal, gas or oil. Therefore, nuclear-generated electricity will be more and more competitive with other electricity sources, in spite of the high initial investment cost.

A simple back-of-the-envelope calculation can estimate the influence of price fluctuations of raw materials for various energy sources: The relationship between the energy output from equal amounts of natural uranium and steam coal is about 10,000, and the relationship between the present-day price of equal amounts of natural uranium (150 USD/kg U) and steam coal (150 USD/t coal) is 1000. Therefore, an increase in the current price of uranium by a factor of 2 (when very-low-grade uranium enriched rocks become mineable, and also seawater mining may be feasible) would have only 10 % of the impact on electricity price compared to the same amount of price increase for steam coal. The same calculation is, of course, much in favor of solar energy for which solar radiation comes free, but the price of large-scale conversion into electricity is currently still prohibitive.

There is an enormous potential of cheap electric energy from nuclear power, limited not by natural resources, but by political and environmental issues. A particularly intriguing perspective is added by new breeder technology which could provide all energy requirements on Earth in a sustainable manner (i.e. no depletion), as already pointed out by Cohen in 1983.

Literature


Dr. Bernd Lehmann studied geology at the University of Heidelberg and the Free University of Berlin (PhD on tin deposits in Bolivia in 1979), and then was a postdoc at the Harvard University followed by several years as an exploration geologist in Central Africa and SE Asia. Since 1991, he has the Chair of Economic Geology at Technical University of Clausthal and studies all kinds of mineral deposits with a focus on South America.

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Systematic Exploration of Deposits – a Key to Lowering Risk in Investments

using the example of a Diabas deposit in Bosnia

by Univ.-Prof. Dr.-Ing. habil. H. Tudeshki
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The present article is a report of a systematic exploration of a diabase deposit. The goal was to establish a plant to produce natural stone which, in case quality and quantity of the deposit was accounted for, would be used for structural and underground engineering in Bosnia – Herzegovina. The deposit which was to be explored lies south of the city Tuzla in the Ribnica area. The available literature on the geology of Bosnia discloses deposits of diorite and porphyritic diabase for the area around the river Mala Ribnica. In this report, which deals with the geological exploration of this area, the exploration measures and the analysis of the encountered stones is documented and assessed.

Introduction into the Regional Geology of Bosnia

The contemporary regional geology of Bosnia, which is relevant to this project, is mainly the result of the endogenously conditional dynamic processes of the earth crust in the time period between the Permian and the Older Tertiary. In the Permian the so-called Adriatic-Dinaric Plate was united with the Northern Tethys Plate in the area of contemporary Bosnia. In the medial Triassic a rift was formed, consequently the two above-mentioned plates were detached. This happened approximately along the line of Sarajevo-Banja Luka in contemporary Bosnia. The ocean, the Tethys or the old Mediterranean penetrated into this rift, whereby simultaneously basaltic melted mass ascended from the mantle to the bottom of the ocean. The shift of these continental plates continued into upper Triassic and Jurassic and led to the formation of a new oceanic crust. Part of this newly built oceanic crust is the medial Jurassic basalt and dolerite of Ribnica. As a result of the changes in the continental shift direction during the upper Jurassic, a subduction of the relatively young oceanic base to north-east happened in the area of contemporary Bosnia. Due to the sinking metamorphism, stones of basaltic chemism were highly altered. Today the Amphibolites of Krivaja with an age of 170 to 157 million years bear evidence to these occurrence. After the subduction phase there was a renewed change of direction in the continuous shift of plates, so that parts of the already sunk-in plate experienced an thrust fault in the direction of the oceanic bottom. The so-called ophiolitic mélange as a chaotic mix of blocks and slabs, consisting of greywacke, sandstone, schist, periodite, serpentine rock, as well as basalts, dolerites and tuffs of all kinds was formed in the ocean. In the area of Ribnica the ophiolitic mélange contains all mentioned stones. Following this geological phase Flysch was deposited in the ocean. After the closure of the ocean through collision of the plates, the ophiolitic mélange was pushed over the Flysch to south-west. Therefore the Jurassic ophiolitic mélange of Krivaja-Konjuh-Ribnica lies on the Flysch.

Fig. 1: Geological overview of the project area
Specific Geology of the Explored Area

In the Bosnian geological documentation the Dolerite of Ribnica is called the biggest doleritic mass of Bosnia. In the geological map 1:100,000 (sheet Zavidovići) the following stone deposits are registered in the area of Ribnica: Diabase (ßß), Dolerite (vßß), Spilite (ßßab), amphibolitic Micro-Gabbro (vam) and Amphibolitic-Dolerite (Avßß). The pillow lava provide indications for the position of the former oceanic crust. The following figure reveals a section from the mentioned geological map. The study area is marked on this section.
Primary exploration of the Deposit at Mala Ribnica

In order to verify the general geologic statements of the available literature, a site inspection was carried out. The inspection was carried out in two stages, firstly on the area between the rivers V. Ribnica and M. Ribnica, and then concentrated on the area southwest of the river Ribnica. The goal of the inspection was to use existing natural and artificial exposures to obtain information about the course of the deposit and the composition of the mountains. In parallel samples were taken from relevant spots in the area and from an existing exposure for laboratory examinations.

While inspecting the northern part of the area between the mentioned rivers, it was not possible to confirm the statements from the literature or the geological maps. Fine grained rocks with porous characteristics were spotted at the natural outcrop. In a relatively big, artificially created exposure rocks with low strength and high crumbling characteristics were encountered. The microscopic examinations of the taken samples show that the rocks consist of ash tuff, boulder tuff as well as green schist.

In order to capture the mineralogical composition of the taken samples and the ascertainment of the genesis and strength, thin-section microscopy and x-ray analysis was conducted. The investigation showed that the rocks in the investigation area mainly consist of non-weatherproof tuff. The thin-section microscopies disclosed a hardened ash tuff with changing grain size and composition. The x-ray analysis revealed that the rocks are mainly composed of chlorite, analcim, hornblende and albite. The strong disintegrating nature can be attributed to the relatively high proportion of albite.

Following the negative results of the area inspection of the northern part of the river Mala Ribnica, the work was concentrated on the area south of the river. In the first inspection already it was noticed that this area possesses a better rock capacity. Along the way pillow lava structures were noticed here and there, alongside tuff sediments. The thin-section microscopy and x-ray analysis showed the same result. Besides strongly hardened boulder tuff, dense Diabase and dolerites were found.

Summarized Assessment of the results of the Primary Exploration

The regional geological data account for a diabase deposit in the examination area. However, the on-site inspection and the corresponding examination of the existing outcrops, including the examination of the samples, show a different result. The examination area Ribnica needs a differentiated inspection. The examination area in the north of the river Mala Ribnica shows no deposits that are suitable for the production of natural stone. The area south of the river Mala Ribnica provides indication for the existence of suitable deposits. Although here also boulder tuff were detected, samples of dense diabase were also found. It is assumed that the overlying rock consists of an alternation of diabase, dolerite and ash tuff and it was recommended to concentrate all further exploration to the southern area. For this reason and in order to reduce the total outlay, an accurate picture of the deposit should be obtained through consecutive explorative steps through drillings and diggings.

Secondary Explorative Work

Within the framework of the exploration of the diabase deposit, altogether 11 horizontal boreholes with a distance of 100 m were drilled into the steeply inclined rock. Below photographs document the exploration work, as well as the extracted drill cores. Partly the unsuitable quality of the stone is clearly perceptible during visual examination.

Fig. 4: Transparent cut of a Brockentuff-sample
of the cores. The consecutive laboratory tests, which were documented in form of thin section microscopy, reveal that no coherent deposit of dolerite and diabase, which would be suitable for a quarry, can be accounted for.

The predominantly encountered rock is greenstone. In addition to that, due to their geological past, the rocks in the area of Ribnica clearly contain zeolithes, like for example Analcim, Wairakite, as well as Thomsonite (all from the group of Silicate-hydrates). Once exposed to air and weather, the zeolites cause a quick collapse of the rocks. This occurrence is called “Sonnenbrenner” (sun burn) in the German language.

The rock material encountered in the exposure drillings do not at all meet the quality requirements for construction material. Even small dynamic strains lead to decomposition of the material, particularly when the rock encounters air.

As a result of the above-mentioned research, the exploration work was stopped and the project closed.

Conclusion

The geologic literature of Bosnia reports on deposits of dolerite and porphyric diabase for the area around the river Mala Ribnica. This report deals with the geological exploration of this area and documents and assesses the measures to explore and analyse the encountered rocks.

Originally the project aimed at disclosing the position and quality of the alleged deposits, and in case of discovering suitable raw material, the project was intended to find ways for mining exposure of the deposit (planning of a quarry).

Originally the project aimed at disclosing the position and quality of the alleged deposits, and in case of discovering suitable raw material, the project was intended to find ways for mining exposure of the deposit (planning of a quarry).

Here, altogether eleven usable horizontal exposure drillings were brought down from the way which took course parallel to the river and drill cores were obtained and some diggings were produced. The drill cores were inspected on site and photographically documented. Selected core samples were examined for a detailed analysis of their composition and quality through laboratory tests like thin-section microscopy and x-ray diffraction analysis.

Within the framework of this geological exploration it was not possible to identify deposits of dolerite or diabase, which were coherent enough and suitable for the operation of a quarry. It was only in two of the eleven drillings that conditionally suitable material was encountered. The drilled rocks consist mainly of greenstone or boulder tuff, with a high proportion of zeoliths, (Analcim, Wairakite, mixed crystals of Analcim and Wairakite, Thomsonite), which on their part again cause sunburn. Even small dynamic strains lead to decomposition of the material.

As a result of the findings of the exploration it was recommended to abandon further investigation.
The current article reports on a systematic approach to modernizing the mining and processing techniques in a quarry, while increasing the annual capacity and production quality of producing aggregates for structural and underground engineering.

The mine is located near the city of Sheleiki in Russia. The city of Sheleiki lies in the province of Karelia, approximately 500 km northeast of St. Petersburg, at the sea of Onega, which is the second largest sea in Europe. One main focus of developing the project was the selection and dimensioning, as well as the installation and start of operation of the processing plant through Sandvik Mining and Construction Central Europe GmbH as general contractor, in cooperation with Gerwin Silotechnik, Beckum, Germany, K2 Automation GmbH, Bretzfeld, Germany as well as FB Filter Bau GmbH, Rodenberg, Germany as sub-contractors. On the other hand the focus was planning of the location of the processing plant, as well as planning of the surface mining, under specific consideration of the location of the primary crusher by the MTC planning bureau.

Materials Preparation Technology

In the run-up to the mining planning, the design of the future processing plant was done according to the specifications of the open pit cast administration. The system concept envisages a step-wise development of the processing between the initial capacity of 450 t/h in the first phase and 600 t/h in the final phase, subject to the trend of the market. A systematic network map (Fig. 1) was developed to ensure an economic operation through an early completion, as well as start of operation of the processing plant. The plan was gradually implemented in approximately 37 weeks, starting from the first considerations to the production of the plant.
The standard option, which is displayed in picture 2, allows for a production of approximately 300 – 400 tons of material per hour at a power output of approximately 450 t/h, in the following sizes:

<table>
<thead>
<tr>
<th>Graining</th>
<th>Maximum proportion share of badly formed (GOST)</th>
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</thead>
<tbody>
<tr>
<td>25-60 mm</td>
<td>25 %</td>
</tr>
<tr>
<td>5-10 mm</td>
<td>15 %</td>
</tr>
<tr>
<td>10-15 mm</td>
<td>15 %</td>
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<tr>
<td>15-20 mm</td>
<td>15 %</td>
</tr>
<tr>
<td>5-20 mm</td>
<td>15 %</td>
</tr>
<tr>
<td>2-20 mm</td>
<td>15 % (in proportion 5-20)</td>
</tr>
<tr>
<td>0-2, 0-5, 2-5 mm</td>
<td>...</td>
</tr>
</tbody>
</table>

The designed plant consists of a station with a primary crusher with a feed hopper of a 60 m3 capacity, a feeder, a primary screen, as well as a jaw breaker of type JM1511. The pre-crushed material with a graining of 0-300 mm is conveyed by an underfloor extractor from a dump site with an active volume of approximately 2,700 t, into a Hydrocone H6800 and subsequently it is separated into sand, reference material for the third breakage level, rubble and recycled material on a CS173III screen. The third breakage level consists of two Hydrocones of the H4800 type, whose products are classified into end products on two CS173III screening machines.

The plant is equipped with a de-dusting plant with a capacity of 70,000 m3/h. All machines and handover points are covered by this de-dusting plant, with the exception of the primary crusher plant.

**Opencast Pit Planning**

A three-dimensional model of the deposit was created, based on the collection and incorporation of topographic data of the opencast pit and the relevant environment, including the results of the exploration. This provided the basis for further planning, as well as for the area and mass balancing, separated by residue and ore.

Taking into consideration that the Sheleiki mine was a running operation, which was to be modernized while maintaining the current production, the mining planning was done as follows:

- Selection and planning of the processing location,
- Appraisal of possible locations for the primary crusher,
- Detailed excavation planning of the appraised versions and
- Selection of the optimum mine development and planning options, respectively.

**Analysis of the current mine Development**

The deposit is located within a hillside, which is slightly ascending from southwest to northeast. In the past the quarry was developed in the south west of the area designated for excavation, and has been further developed along the southeastern border over two beds in a relatively narrow form. The extraction is done through drilling and blasting. The excavated material is loaded through a loader and is transported to a mobile processing plant with small mining trucks.
Fig. 2: Flowchart of the new processing plant from Sandvik* in the Sheleiky Quarry

Please note!
The figures on separation sizes and product fractions correspond to Russian standard with round holes on laboratory screens. The figures in ( ) correspond to European standard with square holes on laboratory screens.
Taking into consideration that the modernization of the processing plant, including the installation of a new semi-stationary primary crusher plant was to be done with running mine operation and production, the following planning parameters resulted:

- Selection of the location for the processing plant and the primary crusher,
- As early as possible installation of the new primary crusher plant and the processing
- Running of the existing plant during preparation and installation of the processing plant and the primary crusher,
- Optimization of the route of transport between the extraction locations and the primary crusher plant
- Ensuring the future extension and enlargement of the mine, as well as
- Complete usage of the deposit, as far as technically and economically worthwhile.

The planning goal of a quick installation of the plant and the corresponding need for little mass movements for creation of a suitable, long-term site was achieved through the selection of the permitted south-western area. Furthermore this site has the advantage of lying directly at the mine access road and allowing a clear division between the mine operation and the shipment.

As a basic principle one should strive to install a primary crusher in the area of the center of gravity of the deposit or on a level, which runs through the center of gravity of the deposit. However, due to the form and spatial condition of the deposits in the area this goal is seldom achieved, particularly while planning new opening-ups. In the current case the realization of this issue would lead to conflicts regarding the requested short installation time, the complete extraction of the deposit, as well as avoiding the crossing between transport belt and discontinuous conveyance through trucks.

After balancing all planning requirements and considering an economical transport of the extracted raw material, the location of the primary crusher was selected directly at the western excavation border. This site offers a good possibility of link between the mine and the processing plant. The trucks unloading can be done on a level of approximately 92 m above sea level. The crushed raw material is connected through a belt conveyor system with the primary dump at approx. 92 m above sea level. From there the material is transported with a underfloor reclaimer to the processing plant.

The result of the three-dimensional planning of the site is displayed in Fig. 5. The masses which need to be moved for preparation of this site are approx. 115,000 m³.
**Mine Design**

An integral aspect of ensuring a sustainable and economic operation of a bedrock surface mine is the successive optimization of the in-house transportation costs. As a result of the excavation the distance between the loading site and the primary crusher continuously increases, and needs to be counteracted through transfer of the primary crusher plant and the elongation of the belt conveyor system to the processing. The technical prerequisite consists of the usage of a semi-stationary primary crusher, which can be implemented at a given time with a justifiable economic cost. The technical planning of the mine should always include the consideration of this possibility and should verify this through an economic examination.

The necessity for planning was integrated within the framework of this project. Thereby two excavation options, which take into consideration the transfer of the primary crusher, were planned and compared. The following technical parameters were used, irrespective of the particular planning option:

- **Height of the benches** 12 m,
- **Incline of the excavation slope** 78°,
- **Width of the benches at least** 30 m,
- **Width of the roadway** 15 m,
- **Incline of the ramp** 10%.
- **Final berm width** 5 m and
- **Creation of several working benches for quality management.**

**Planning of the Excavation option 1**

In the first excavation option it was assumed that the primary crusher is transferred to a central location on the level of the center of gravity, after an appropriate progress of the surface mining. Hereby first the AUF-SCHLUSS of the mine north of the primary crusher was started and the excavation was laminary expanded to the north and east. The connection of the first brines was done along the western border. In the second step the upper worked stratum was led to its final state in the eastern and southern direction. It is only in the third phase of the excavation development that, after preparing the location of the primary crusher and the associated belt ramp for many years, that the primary crusher can be transferred.

The balancing of the extracted masses shows that the transfer of the primary crusher can only materialize, approximately 18 years after the startup of the mine. The mine is successively led into depth in further excavation steps. (Fig. 4 to 7).
An initial analysis of this planning version reveals the following problems:

- The transfer of the primary crusher leads to a significant reduction of the extractable masses
- A crossing of the conveyor trace and the passage of vehicles is unavoidable in open pit mines
- The ramp alignment is cumbersome, its establishment leads to a reduction in output during the mining operation
- The excavation field is divided into two areas by the location of the belt conveyor system

Excavation option 2

Due to the above-mentioned disadvantages of the first option, the second option attempted to plan in a way, that a later transfer of the primary crusher can be done to the border of the open pit, to the extent possible. Furthermore it is recommended to plan the future location in the northern direction, since the deposit has a higher thickness in this section. Detailed planning revealed, that the goal of installing the primary crusher in one step on the layer of the center of gravity at the level of 76 m above sea level is only possible after 24 years. Therefore the planning was done in a way, that the primary crusher can be transferred twice, once 15 years and once 23 years after the startup.

The respective planning phases up to the ultimate pit design are displayed in Fig. 8 and 9. The first two planning steps correspond to the first excavation version.

This planning option was coordinated with the management of the mine, as well as with Sandvik Company and was implemented. The project was completed according to schedule. The production with the new processing plant is successfully taking place since fall 2006.
Conclusion

The present article makes it clear that sustainable economic advantages can be achieved through a systematic approach and timely interlocking of planning and project planning of a big processing plant, as well as the planning of the pertinent mining operation. This large-scale project was realized in less than 40 weeks, while at the same time ensuring the existing mobile processing. Project goals were fully accomplished and the open pit mine Sheleiki is in operation since 2006.

Following is a documentation in photographs of the new processing plant.
Analysis to register dust emissions while handling mineral coal

A comparison between emission factors from VDI standards and measurements

by Univ.-Prof. Dr.-Ing. habil. H. Tudeski¹, Dipl.-Ing. Tao Xu¹, Dr.-Ing. W.-M. Feldbach²

¹Department for Surface Mining and International Mining | Clausthal University of Technology | Germany
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The article reports on results of an analysis to register dust emissions while handling mineral coal. Within the framework of this project the dust measurements were conducted for dust emitting operations on the company site of Rhenus Midgard GmbH in Nordenham location. This was done with the goal of determining values for dust emissions, and comparing them with requirements of VDI-guideline 3790, in order to introduce technically meaningful measures to reduce emissions.

Rhenus Midgard GmbH owns and operates at Nordenham in Northern Germany a seaport, where already for more than 100 years bulk goods like i.e. coal, petrol coke, iron ore pellets and construction materials are handled and temporarily stored.

The materials handling amount currently is around 2.5 Million tons per year. Since the demand for raw materials increases during the last years, an expansion of the port areal in Nordenham is planned.

Over the years in the close-by area to the port a dense housing construction developed which often lead to conflicts with adjacent residents due to dust emissions.

Trough several dust protection measures Rhenus reduced these emissions in a remarkable dimension. Furthermore, the company commissioned a study entitled „Investigation on an analysis to register dust emissions while handling mineral coal“. Whithin the frame of the study dust measurements for all dust-relevant work operations have been carried out on the port area.

Based on these findings further technical and effective arragements can be initiated in order to reduce dust emissions, that even exceed the statutory required measures.
Although the VDI-guideline 3790 explains a procedure to measure dust emissions and describes how to estimate the occurring emissions during the handling of bulk solids, it also stipulates that on-site measurements should be preferred, since such measurements always have a higher accuracy. It was for this reason that initially an analysis of operational cycles was conducted, which then led to a definition of dust emitting operational procedures.

During further proceedings a measuring concept was developed for these operations, which included the selection of suitable measuring instruments, as well as the exact procedure of measurement, the documentation of measuring results and their analysis. Based on their characteristics of emission, the defined work steps and test points were divided into categories, such as continuous and discontinuous point sources, line sources, as well as area sources.

The measuring results have shown that the procedure described in the VDI-guideline 3790 to estimate dust emissions leads to the assumption of clearly too high dust emissions at the Nordenham location. In comparison to the on-site determined dust emissions, the values calculated according to VDI were clearly too high for most of the test points. It was only for two dust sources that the procedure of VDI leads to lesser values than in the on-site measurements.

This result shows that the emission values determined on-site should be used for further considerations of emission development in the Nordenham location. It is only through this approach that it is possible to introduce meaningful measures to reduce dust. This is also relevant to other operation sites with the same or similar operations related to emission. Therefore we would recommend using the emission values resulting from the present measurements, instead of the calculated values from the VDI guidelines. In case of differing local conditions or operations, we suggest conducting additional measurements, in order to achieve strong measurement results.

Introduction

Approximately 70 million tons of mineral coal are used annually for energy- and steel production in the Federal Republic of Germany. Both the internal production, as well as the approximately 44 million tons of imported coal need to be distributed systematically, according to their quality and quantity and based on the location of the users. In the European area outside of Germany this stream of material is currently coordinated in Rotterdam, and in Germany itself this is done in Hamburg Hansaport, as well as in Nordenham. Due to the positive development in the coal power and steel generation, as well as the reduction of the coal handling capacity of the power stations in Hamburg Hansaport, there is a definite need for expansion and establishment of new locations for coal handling in the Federal Republic of Germany. For the Industry stationed in Germany this need takes up central importance, particularly in light of the necessity of the state development, in the economic competition with the neighboring country Netherlands. Possible locations to be developed could be reloading points at the Elb, Weser and Jade river.
The dust resulting from the handling of this material and the consequent immission in the neighborhood assumes a central role, both in the maintenance of existing coal handling locations, as well as for future approval of operation sites.

In this connection the protection of the neighborhood is one of the basic strategic milestones of operation and obtaining approval.

The company Rhenus Midgard GMbH & Co runs a private harbour in Nordenham, which among others has a yearly transit turnover of approx. 500,000 tons of mineral coal. The pier, which lies along the Weser river, extends 2.5 km from northeast to southwest, with a maximum width of approx. 450 m from east to west. The total capacity is 2.5 million tons. The coal handling is done on a length of approx. 600 m, in the area of the north pier and its extension.

While handling in the western dumps is done through rail-bound mechanisms for loading and unloading, the management of the dumps in the back, which are laid out from east to west and are long stretched is done through a wheel loader in a discontinued operation.

Assembling and dismantling the dumps of this section is practiced through load and carry system. In addition hydraulic excavators are used for the structuring of the dumps above track level. Therefore it can be said that the site has various sources of dust immission in different locations, as well as diverse mobile sources of varying modes of operation.

Due to the very short distance to constructions and residential properties respectively, in the past there have been efforts to combat dust and to protect the residents. This has included the building of water pipes for establishment of irrigation plants at 23 locations in the site, as well as a computer supported control of 2-3 raining units. Moreover, for some time there have been efforts to seal the dump surfaces against wind through irrigation with environmentally friendly binding agents.

The initial measurements done by the enterprise at three locations, show that the coarse dust (non-health threatening dust particles bigger than PM 10, according to 22 BImSCHV and TA-air respectively) does not exceed the threshold value of immissions. Nevertheless the company Rhenus Midgard GmbH & Co KG strives to introduce meaningful measures to reduce dust. In order to do this, it is planned to introduce technically meaningful and economically acceptable solutions for a heavy reduction of dust development, irrespective of guidelines and reference values of relevant norms.

The tests are planned to be conducted with the aim of using the suggestions for solutions as a basis for the approval and start of operation of future company-owned re-loading points, once practically tested.

Based on these requirements, the goal of the research has been a systematic analysis and assessment of the Nordenham operation, the identification of sources of emission, the registration of the resulting source-oriented immission, based on quality and quantity, depending on effective influencing parameters, and in the end suggesting effective technologies to eliminate and alleviate the problem respectively, through inclusion of international experiences.
Analysis of operation cycles and dust development

The handling processes in the Nordenham harbour consist of the unloading from a ship (arrival of the coal from abroad), the loading on train and river boats (transport within Germany), the transfer between the storages, as well as the additionally needed trimming works in all areas of the operation site. The registered operation cycles include the gripper operations, the belt transport, trimming works, as well as train loading. The roadways, dumps and free spaces were also examined on the basis of their dust emissions. Although the dumps on the operation area of the Rhenus and the surrounding free spaces are not included in the operation cycles, they are considered considerable dust emitters and therefore are taken into account.

Clamshell Operation

The UMSCHLAG bridges in Nordenham and the DREHWIPPKRAN to load and unload the ships respectively are equipped with gripper installations. In the gripper operations there are basically three operation cycles. These are the unloading of the ships, the loading of the trains and the loading of the river boats.
Band Handover and Release

Beginning at the discharge funnel of the bridges, as well as the revolving crane, the coal, which is unloaded from ships, is transported by belt conveyor systems to the respective dumps.

Trimming Works

Trimming works are necessary at various locations and times of the operation area. For these needed trimming works mainly wheel loaders, chain dozers and hydraulic excavators are used. These resources are only auxiliary appliances for the actual loading and unloading of bulk cargo.

Loading on Trains

In order to load the coal on trains, the gripper of the transit turnover bridges of the storage areas takes up the coal and transfers it to the feeding hopper. First the coal is weighed by a scale which is positioned under the funnel, and then it is conveyed to the waiting wagons.

Roadways

During turnover of bulk cargo, driving movements of wheel loaders are inevitable. Moreover driving movements of wheel loaders and chain dozers occur in all areas of the operation site. Driving movements are always combined with dust emissions, which occur due to blowing up of the dust lying on the road. The continuous milling of the coal, which is caused by the driving, has an additional negative effect on the extent of the dust emission.
Dumps and Free Spaces

The dumps must be separated by sealed and unsealed dump areas. The sealing is done by a water truck after trimming of the dump, and besides water it also contains the anti-dust and sealant Innocoat. A sealing is mainly done in locations, where the coal is to be stored for a longer period of time. There is almost no dust emission from these sealed dump areas, as the fine fraction is bound to the Innocoat and the dump surface is undisturbed for any length of time. Unsealed dump areas (fracture paths) are encountered in operational areas, where coal is quickly reloaded or continuously taken away.

Apart from the operationally needed dumps, the emission potential of free spaces should also not be underestimated. In this regard the free spaces, on which the coal is highly milled through the driving movements of wheel loaders or other vehicles, are particularly problematic.

Dust Sources and Measuring Points

The operating procedures, which were recorded onsite in the Nordenham harbor, yield 16 dust sources and measuring points, respectively, which are listed in Table 1.

Tab. 1: Dust Sources and Measuring Points

<table>
<thead>
<tr>
<th>Measuring point</th>
<th>Description of the Emission Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring Pt. 1</td>
<td>unloading from ship - gathering of rock pile through grippers</td>
</tr>
<tr>
<td>Measuring Pt. 2</td>
<td>dropping from grippers into funnels</td>
</tr>
<tr>
<td>Measuring Pt. 3</td>
<td>dropping from grippers on dumps</td>
</tr>
<tr>
<td>Measuring Pt. 4</td>
<td>belt handover</td>
</tr>
<tr>
<td>Measuring Pt. 5</td>
<td>dropping from belt against height of dropping</td>
</tr>
<tr>
<td>Measuring Pt. 6</td>
<td>trimming works by chain dozers</td>
</tr>
<tr>
<td>Measuring Pt. 7</td>
<td>route of chain dozer</td>
</tr>
<tr>
<td>Measuring Pt. 8a</td>
<td>trimming by wheel loaders – taking up rock piles</td>
</tr>
<tr>
<td>Measuring Pt. 8b</td>
<td>trimming by wheel loaders – dropping off rock piles</td>
</tr>
<tr>
<td>Measuring Pt. 9a</td>
<td>route wheel loader - loaded</td>
</tr>
<tr>
<td>Measuring Pt. 9b</td>
<td>route wheel loader - unloaded</td>
</tr>
<tr>
<td>Measuring Pt. 10</td>
<td>take up of gripper on the dump</td>
</tr>
<tr>
<td>Measuring Pt. 11</td>
<td>dropping of gripper on the river boat</td>
</tr>
<tr>
<td>Measuring Pt. 12</td>
<td>delivery of coal into the train wagon</td>
</tr>
<tr>
<td>Measuring Pt. 13</td>
<td>dumps, sealed or unsealed / fracture surface,</td>
</tr>
<tr>
<td>Measuring Pt. 14</td>
<td>dry free space</td>
</tr>
</tbody>
</table>

Fig. 7: Dumps and free spaces
Measure Concept

In order to compare the intensity of emission of the various dust sources, a specific emission factor with a unit of g/h is determined for each dust source. Furthermore the compliance with the required thresholds can be checked with these factors.

The developed measuring principle is based on the measurement of differences. In the process the occurring dust concentrations in the air are metrologically registered in short time intervals for the respective dust sources, both on the Luv- as well as on the Lee side. The pre- and total load respectively results from generation of the average value. The difference of both values provides the additional burden, which results from the mere activity of the handling of the material.

Taking into consideration the geometric dimensions, the respective emission per mass unit can be determined. Subsequently the emission factor can be determined by applying the mass drawn emission value to the handled amount or to the operating time of the various dust sources.

The measuring concept is developed to determine emissions of divers sources while handling, transporting and storing coal. In order to determine or realistically estimate the actual emissions, it is necessary to measure the immissions around the separate sources under real handling and storage conditions, as well as under various climate conditions.

The measuring concept chosen in this project, as well as the instruments used are qualified to capture particle sizes from less than 1 µm to 32 µm in various particle sizes. In a study conducted beforehand the particle size of the dust emissions occurring in the Nordenham site were dealt with through REM-photographs. This analysis proved that, in case the instrument has a distance of 6 m to the location of emission, the incoming dust-filled air contains almost no particles of a particle size larger than 30 µm. Therefore it could be authenticated that the chosen and applied measuring instruments for the measurement of the dust emissions on the operation area of the Rhenus were appropriate.

<table>
<thead>
<tr>
<th>Picture</th>
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<td>Summe</td>
<td>6</td>
<td>58</td>
<td>1.733</td>
<td>1.797</td>
</tr>
<tr>
<td>%</td>
<td>0,33</td>
<td>3,23</td>
<td>96,44</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 8: REM-Photograph, 500 times magnified

Tab. 2: Analysis of the REM-Photograph
Implementation of Measurements

For each measurement the examined operation procedure (point of measurement), the location, date, time of measurement, as well as the climate conditions (outdoor temperature, wind direction and speed) at the time of the measurement was captured and documented. The location of the measurement was determined with a map of the operation area, on which a grid was placed. Through this an exact assignment of locations was possible for each measurement.

In order to acquire statistically secured values, each measurement was repeated 10 times at most possible identical conditions, irrespective of the chosen procedure. The measurement results and all other measuring parameters, as well as other characteristics which occurred during the measurements, were registered in a special documentation system.

Measurement Results

The measurement results were subdivided into point-, line-, and area sources. Furthermore point sources were divided into continuous and discontinuous emission sources.

Basically the emissions of the separate dust sources (measuring points) were initially calculated with the help of the VDI-guideline 3790. Subsequently the emissions were determined and compared with each other on the basis of own measurements. The respective higher emission factor of the two procedures was used for further proceedings. This is in accordance with the usual proceeding in a worst-case scenario. The analysis of the measurement results was done in a display of the emission factors for all emission sources in the particle size classes PM2.5, PM10, as well as dust in a particle size of 10 to 32 µm.

The result showed that in most of the cases the measured emission factors lie clearly below the VDI-guidelines. The following picture shows the emission factors according to VDI-guidelines, the calculated emission factors according to the conducted measurement program, as well as a percental statement of the relation of these two emission factors to each other.

![Fig. 9: Distribution of the measurement locations and number of measurements](image-url)
In the area of discontinuous point sources (MS 1, 2, 3, 8a, 8b, 10, 11, 12) it was ascertained that the determined emission factors lie clearly below the VDI-values in all cases. It was only in the area of the rock pile pick-up on the dump (MS 10), as well as on the dropping by the gripper on the river boat, that values comparable to the VDI were encountered, whereas the determined values also lie under the VDI values by the factor 2. The higher measured emission values of these two emission sources are due to the consideration of loading of dry coal, which hardly ever occurs in practice. In the continuous point sources (MS 4 and 5) the measured emission factors were below the values of the VDI-guidelines by the factor 2 and 6 respectively. This trend could also be seen in the line sources (MS 6, 7, 9a, 9b). Here the measured emission factors reached a maximum share of 60% of the VDI-values. The area sources portray another picture, as here the VDI values were partly exceeded by the factor 5 (MS 13 – fracture surfaces). However, this extreme value was based on the inspection of dry fracture surfaces, which rarely occur in practice.

Defined measurement results

Based on the analysis of the results, measuring values were defined for all measurement points. These values were divided in point, line and area sources and used for the consecutive simulation of the expansion.

Metrologically the particles PM2.5, PM10 and dust with a particle size between 10 and 32 µm were captured, however the simulation program requires a specification in the particle sizes

- 0 to 2.5 µm,
- 2.5 to 10 µm,
- 10 to 50 µm as well as
- 50 to 500 µm.

Therefore correction of the measurement results was needed and the measurement results were supplemented with the emission factors for dust in a particle size between 50 and 500 µm. These values could not be determined metrologically and could only be estimated by means of the particle size analysis (share of this particle size) and the measurement results of other particle sizes (PM2.5, PM10, dust between 10 and 32 µm). The defined measurement results for the following simulations are described in the following tables, subdivided into point, line and area sources.
### Character of the emission source

#### Measuring Point

<table>
<thead>
<tr>
<th>Character of the emission source</th>
<th>Measuring Point</th>
<th>Determined Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 to 2.5 μm [g/h]</td>
</tr>
<tr>
<td>continuous point sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3,0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5,0</td>
</tr>
<tr>
<td>discontinuous point sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0,3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0,4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0,5</td>
</tr>
<tr>
<td></td>
<td>8a</td>
<td>0,3</td>
</tr>
<tr>
<td></td>
<td>8b</td>
<td>0,2</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>3,3</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>1,8</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0,3</td>
</tr>
</tbody>
</table>

#### Tab. 4:
Defined Emission factors, point sources

### Character of the emission source

#### Measuring Point

<table>
<thead>
<tr>
<th>Character of the emission source</th>
<th>Measuring Point</th>
<th>Determined Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 to 2.5 μm [mg/m]</td>
</tr>
<tr>
<td>Line sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3,0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>2,0</td>
</tr>
<tr>
<td></td>
<td>9a</td>
<td>18,0</td>
</tr>
<tr>
<td></td>
<td>9b</td>
<td>23,0</td>
</tr>
<tr>
<td></td>
<td>route dry</td>
<td>23,0</td>
</tr>
<tr>
<td></td>
<td>route wet</td>
<td>0,4</td>
</tr>
</tbody>
</table>

#### Tab. 5:
Defined emission factors, line sources

### Character of the emission source

#### Measuring Point

<table>
<thead>
<tr>
<th>Character of the emission source</th>
<th>Measuring Point</th>
<th>Determined Emission Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area sources</td>
<td></td>
<td>0 to 2.5 μm [mg/m]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dump sealed</td>
<td>&lt; 0,1</td>
<td>&lt; 0,1</td>
</tr>
<tr>
<td>dump unsealed</td>
<td>&lt; 0,1</td>
<td>0,8</td>
</tr>
<tr>
<td>fracture surface</td>
<td>237,0</td>
<td>182,0</td>
</tr>
<tr>
<td>14</td>
<td>16,6</td>
<td>198,4</td>
</tr>
</tbody>
</table>

#### Tab. 6:
Defined emission factors, area sources
Simulation of a typical Shift

Subsequently, within the framework of the simulation, a typical shift in the operation area in Nordenham was emulated. For this purpose all working processes that occur during a shift were described and were assigned to a location in the operation area. This mapping was relatively easy for point sources, because the exact location of the emission sources was captured within the framework of the measuring programme. A localization of the line sources could also be done with the help of the captured routes. However, for the area sources presumptions had to be made. For the area sources it was presumed at the time of the simulation, that approximately 90% of all open areas are in wet condition and only approximately 10% are in dry condition. In the simulation the predominant part of the dumps was in a sealed situation, except a part of the storage in the southern area of the operation area. For a second simulation the share of the dry free areas was reduced to 0%, in order to demonstrate the influence of a complete and lasting irrigation. During the simulation a typical operation cycle of a day was modeled and it was assumed that this cycle is repeated every day for the duration of one year. For the occurring wind in the simulation period of one year the statistics for the wind classes for the location was used. The results of the simulation are displayed in the following Figures 10 and 11.

While calculating the deposition of the dust it could be shown in this simulation, that the dry free areas have a very high influence on the total dust deposition. An increase of the dry share of the free spaces from 0% to 5% already increases the total deposition of the harbour in the surrounding area of the operation to such an extent, that other dust sources have almost no influence. This underlines the need to basically always keep all free areas moist.

Recommendation

The following dust sources were identified as significant dust sources, that are characterized by an elevated annoyance potential:

- belt handovers,
- trimming works of the chain dozers with dry material,
- dry routes of the wheel loaders,
- unsealed coal dumps,
- dry fracture surfaces as well as
- dry free areas.

Measures to reduce dust should be implemented at these dust sources. Locations of belt handover belong to the continuous dust sources. With identical turnover of material and identical conditions, the emission of a continuous source is always higher as that of a discontinuous source. For this reason the locations of belt handover should
preferably be encapsulated. With this a reduction of the dust emission of approximately 90% can be achieved.

In case trimming works are done with dry material, or if the driving route of a chain dozer is dry, this can lead to elevated dust emissions. If such conditions are noticed during Trimmarbeiten, the material should be kept moist.

According to the results of this study, the emissions of a dry route can be higher, compared to a moistened route, and this by a factor up to 100. Therefore all routes of the wheel loaders should always be kept moist.

Due to the extent of their area, the unsealed coal dumps can turn into significant dust emitters. For this reason all coal dumps should be sealed to the extent possible. In case the seal of a dump is broken open, fracture surfaces come into being. Normally these surfaces are in a moist condition and only emit little dust. However, in case they dry up in pertinent weather conditions, the fracture surfaces offer a good possibility for the wind to strike due to their large surface and mostly very loose bedding of material, so that high emissions can occur. It is for this reason that fracture surfaces should always be kept moist, particularly in dry weather, or they should be sealed at an early stage after the work is finished or in case of longer stoppage of work. Furthermore it should be noted that the orientation of the fracture surface to the direction of the wind has an influence on the level of the dust emission. Therefore fracture surfaces which lie parallel to the wind direction and are expected to generate most annoyances (eastern wind), should be avoided to the extent possible.

Free areas are great dust emitters in a dry state. Therefore all free areas should be kept moist, even at locations that are difficult to reach.
Mine safety – a fundamental success parameter for coal mining in Germany

by Dr.-Ing. R. Schumachers | RAG Aktiengesellschaft | Herne | Germany

RAG Aktiengesellschaft is generally acclaimed for its state-of-the-art mining technology and high health and safety standards. Recent years have seen the development of successful new mining practices along with the introduction of an extremely effective safety at work system. The company’s long-term safety strategy and up-to-date management system, which have been based on an innovative health and safety policy and a dynamic organisational and procedural structure, create the framework that is required for a successful industrial safety record. This paper will present a number of examples showing how mine safety can best be developed and organised and how the workforce can be made aware of their responsibilities and in this way can achieve even higher health and safety standards.

The core business of RAG Aktiengesellschaft is to extract Germany’s coal deposits and all indigenous mining activities now come under its remit. RAG is responsible for three coalfields – Ibbenbüren, Saarland and Rhine-Ruhr – and its 30,000-strong workforce is distributed around eight collieries, coke works and various service sectors. Last year RAG produced around 21 million tonnes of coal from its German-based operations. In spite of production cuts and the general downsizing of the coal industry the company is still able to meet one third of Germany’s total coal requirements.

RAG Aktiengesellschaft provides security of energy supply based on the latest mining technology while at the same time maintaining the highest health and safety standards. The company philosophy is solidly based on three elements: coal production, health and safety, and environmental protection.

Workplace safety and productivity – these two key objectives are an inseparable part of RAG’s remit. Over the years the German coal industry has developed extremely successful and innovative technologies and at the same time has achieved the highest safety standards.

Though the initial situation could generally be described as difficult, RAG has been very successful in the development of its health and safety programme and there has been a marked reduction in the number of industrial accidents recorded above and below ground in all operating sectors. Since 1995, for example, total notifiable accidents below ground have fallen by more than 75%. With exactly 20.3 accidents per million hours worked the mining division has now reached an all-time accident low.

At the same time the industry has increased its underground output per man-shift – and hence its productivity level – by more than 26% to a current figure of 7,071 kg/MS (Fig. 1).

This clearly demonstrates that improving productivity, and hence profitability, goes hand in hand with
reduction in the accident rate. But more than this, a healthy workforce is essential for the economic success of the company. An effective health and safety policy therefore makes a major contribution to wealth creation and helps the company achieve its corporate objectives. Such a corporate philosophy has been the key to our success.

Our health and safety achievements have also been the product of a long-term strategy based on an innovative industrial safety policy and a dynamic organisational and procedural structure.

The old style of health and safety management, which tended to be more corrective and reactive, has now been replaced by a more proactive and preventive approach. Much of this can be attributed to the new sense of awareness and safety conduct of the workforce. The industry in general has now managed to create an environment in which health and safety are now taken for granted as natural management functions. Cooperative and participative health and safety means that all employees are now motivated to apply their own know-how towards identifying and assessing risks and hazards, which enables them to participate actively and autonomously in improving the working environment. All this relies on comprehensive communication and cooperation between the various parties involved (Fig. 2).

We have also reorganised our management system along more integrated lines. In this particular context this means a universal and comprehensive restructuring of the company’s health and safety doctrine as it applies to all sectors, procedures and activities and the general inclusion of all factors capable of leading to industrial accidents, work-related illnesses or occupational diseases.

An integrated health and safety system naturally requires an intensive analysis of all potential operational risks and hazards together with a complex examination of how all these factors impact on the workforce, finally ending with the introduction of an appropriate set of measures.

According to our view of industrial safety it is not possible to separate the key aspects involved, namely human behaviour, organisation and technology. Advances in creating safer and more healthy workplaces and working conditions are only possible if these three key areas are effectively coordinated and if each individually achieves a high standard. This essentially makes modern health and safety a management responsibility (Fig. 3).

I would now like to present a number of technical, organisational and conduct-related measures that RAG has successfully introduced for improving the company’s occupational health and safety performance.

In recent years we have succeeded in further improving safety standards at our various collieries and associated facilities by employing and developing innovative technologies and by making extensive use of standardised plant and equipment. We have developed and introduced targeted technical strategies for our key operating areas, including coalface operations, development drivages, electrical and mechanical engineering, logistics, maintenance and coal preparation. When laying out new production areas our planning teams are already creating the conditions that are needed to ensure that operations such as coal winning, road heading, product clearance, climate control and mine-gas drainage can be carried out safely and efficiently.

Allow me now to present three examples that serve to illustrate the high safety standards that have been achieved by the German mining industry:
An extensive network of densely-concentrated measuring equipment and apparatus now ensures that the entire working area below ground is monitored for risks and hazards. Mine ventilation data, including CH₄, CO and airflow measurements, are constantly relayed to continuously-manned surface control rooms where they are retrieved, processed, analysed and interpreted around the clock in 5-second pulses. These ultramodern safety monitoring stations are able to detect trends at a very early stage in their development so that potential threats can be eliminated or directly counteracted. This helps keep the number of underground fires and methane ignitions down to an absolute minimum (Fig. 4).

As the presence of methane in the mine air constitutes a considerable safety risk every effort is made to prevent methane build-up by draining off the gas before or during the winning phase. The methane is then pumped to the colliery surface through a system of pipes for subsequent utilisation. Approximately 92% of all the gas drained from German collieries is currently used as a fuel, mainly in the 100 or so thermal power generation stations that have been set up to provide power to local consumers (Fig. 5).

Another example of technical innovation in the area of industrial health and safety involves the many and diverse developments associated with the lifting and movement of heavy loads. A large number of chain and sling systems, hoists, manual lifting aids and manipulators have already been developed and heavy items of equipment now feature special lashing points so that lifting tackle can now be employed as a matter of routine. This not only greatly reduces the level of physical stress and fatigue for the transport teams but also helps lower the accident rate (Fig. 6).

RAG attaches great importance to safety training for all members of staff. The latest teaching techniques and equipment are used to provide intensive training in the industry’s special safety code of conduct and each member of the workforce is made aware of all relevant health and safety issues. Here self-responsibility and leading by example take centre stage. In 2007 almost 25,000 man-shifts were expended on teaching sessions and advanced safety training for coal-industry personnel (Fig. 7).
A step-by-step model has now been established as part of the industry’s management development programme and this incorporates occupational health and safety as part of each training seminar (Fig. 8).

Special courses have been developed for each hierarchy stage and sessions are held either at the coal industry’s own training centres or off-site as part of an advanced training programme. Courses last from nine days to six weeks, depending on the stage of development. Career progression essentially depends on success in these training courses and on the trainee’s safety conduct under operational conditions.

The agreement of ambitious qualitative and quantitative targets is also an important component as the industry seeks to improve its health and safety strategy. A vital element in the target-agreement process is to link the plannable and detailed measures to the operating technology, company organisation and conduct of the workforce. An ongoing monitoring programme is used to ensure a prompt response in the event of divergence between the target figures and actual performance. Achieving the health and safety targets agreed with the company management also has financial implications and for this reason a self-responsible approach to continuous health and safety improvement is at all times a key element in the company’s management philosophy. It has been found that the agreement of health and safety targets – combined with concrete measures – acts as a challenge and as a motivation for the workforce. Falling accident rates are a sure indication of this (Fig. 9).

The company project ‘Hazard perception in operating practice’ has now established itself as a particularly effective form of workforce participation. This concept is based on the rationale that activities whose level of risk is perceived to be low are generally associated with fairly high accident rates, whereas activities whose level of risk is perceived as high tend to produce low accident figures (Fig. 10).

Raising risk awareness is achieved as follows:

Employees are asked to assess the level of risk associated with the activities they perform at their place of work. The data obtained from analysing the medical logbook entries are then compared with the subjective assessments provided by the workforce. This serves to illustrate the difference between the actual hazard and the perceived risk. Instruction courses, training programmes and ‘mini-group’ sessions are then used to confront those involved with the error of their judgement and in this way they learn how to make a correct assessment of the level of risk that is present – and by adopting an appropriate code of conduct are therefore better able to prevent accidents.

By correcting this subjective – and
Industrial health protection is also given a very high priority at RAG.

In addition to the numerous projects and measures aimed at reducing accident rates the company has also put in place a series of innovative industrial-health campaigns designed to promote the health and welfare of the workforce. Here I should like to highlight the measures that have been introduced to prevent muscular and skeletal disorders, as problems of this kind are among the most common of all the human ailments.

At RAG muscular and skeletal problems account for more than 50% of all sickness-related absences.

As part of the company’s health promotion campaign to reduce muscular and skeletal problems a special prevention programme has now been developed for all RAG sites. Employees who are considered to be particularly at risk are first identified as part of the routine cycle of medical check-ups. The company medical officer then determines a set of specifically targeted measures. One of the solutions that has proved to be particularly effective for all employees is the opportunity to attend special spinal-column training sessions that are held at one of the RAG’s fitness centres.

The feedback from our employees has been extremely positive since this wellbeing campaign was launched. The training activities can be dovetailed into the working schedules with very little expense and effort and even after only a few months we are already beginning to see early signs of success (Fig. 11).

As a result of this prevention campaign the number of days lost due to muscular and skeletal ailments has been falling steadily by over 40%, namely from 12.2% in 2001 to 7.3% in 2006.

In 2005 a forward-looking, methodical concept was developed for RAG whereby the three key areas of industrial safety, workers’ health and environmental protection were systematically and consistently directed using management-system methods. This overall concept follows the basic principles that underlie any human action:

- Set ambitious targets
- Plan the course of action
- Act according to the proposed plan
- Check regularly that the course is being correctly pursued
- Ensure that any deviations are systematically corrected
- Improve and refine the course of action and set new targets.
These basic elements (targets, planning, implementation, monitoring, correction and improvement) are all used to guide and manage the conduct of the workforce. The management cycle is thereby created by way of a closed-loop control circuit. This cycle is then applied systematically in such a way that health, safety and environmental factors can be more effectively planned and calculated (Fig. 12).

The entire concept is based around three pillars:

- Managing through written target agreements
- Agreement of concrete measures that are tailored to individual situations
- Raising workers’ awareness and changing their behaviour through targeted information and communication.

This action programme also helps to reduce the accident rate.

In conclusion I should like to say that the aforementioned projects and measures have enabled RAG to put in place a successful and practical health and safety management system. Health and safety is now not just a natural managerial responsibility but has become part and parcel of the daily routine.

Yet we are in no way resting on the laurels of our recent success, for further initiatives and actions will be needed if we are to keep pace with technological change and meet the challenges this will pose for our industry in the years ahead.

Dr.-Ing. Rudolf Schumachers, 52 years old, studied mining engineering at the RWTH Aachen, graduated in 1982. Following his studies he was busy with production tasks on several mines of the Deutsche Steinkohle AG, at last as mine managing director. Since 1994 he acts in the central sector “occupational health, safety and environmental protection” at the headquarter of the Deutschen Steinkohle AG, and since January 2005 as authorized expert in the board for workplaces of the federal ministry for work and social aspects. In February 2005 he was awarded with a PhD at the Clausthal University of Technology. Since March 2006 he acts as lecturer for occupational safety and integrated management systems.

rudolf.schumachers@rag.de
**Impressive performance at Basalt-Quarry with Surface Rock Mill**

At Steinexpo 2008, which took place from September 3 to 6, 2008 at the basalt quarry in Niederofleiden near Frankfort, Germany, Vermeer demonstrated the currently largest Surface Rock Mill in the world: the **Terrain Leveler T 1255** - with impressive results.

The Terrain Leveler T 1255 has an operational weight of 110 tons, a length of 12.40 m, a mill drum width of 3.70 m and a variable milling depth ranging from 0 to 60 cm. The width of the undercarriage measures 3.40 m maximum.

The machine is transported in two parts, consisting in the chassis which includes the driver’s cab, and the milling boom with the drum. Demounting the machine can be managed by only two mechanicians within 8 hours. Also the erection of the T 1255 can be done in this time frame. Positively mentioned must be the fact, that neither a crane nor any other hoisting devices are required at the duty area.

The Surface Rock Mill is driven by a 6-cylinder Caterpillar C – 16 engine with a performance of 447 kW (600 hp). The drive of the milling chain and the milling drum operates hydrostatically. The drum is equipped with 160 single bits and can be inclined up to 5° in a way that a GPS- or laser controlled area abrasion can be carried out.

The undercarriage tracks have a width of 76 cm and provide a good stability as well as a adequate surface load.

The cab can be adjusted hydraulically in height an is equipped with an air-suspended rotating seat, air condition system, heating, radio an sun protection window panes.

While in milling operation rock gets loosened, crushed and deposited. The T 1255 moves backwards, the drum can be adjusted to the required milling depth. Via the milling teethes the rock gets crushed out of the formation and placed in front of the machine.

---

As debris a material of a grain size of 0 - 300 mm is produced. The several fractions are normally as follows:

- 0 – 8 mm .... ca. 6 – 8%
- 8 – 32 mm .... ca. 6 – 10%
- 32 – 63 mm .... ca. 15 – 25%
- 63 – 100 mm .... ca. 20 – 30%
- 100 – 200 mm .... ca. 20 – 30%
- 200 – 300 mm .... ca. 10 – 20%

The mined raw material can be handled with available equipment in the quarry and is transported to the processing plant (i.e. crushers and mills).
The application of the Surface Rock Mill is expedient from technical and economical point of view when the following aspects are fulfilled:

• Application of the T1255 as replacement for blasting
• Laminar and accurate mining up to predetermined coordinates
• Mining of homogenous material
• Partition of overburden and ore
• Mining of deposits which are settled as stripes or seams
• Alternating duty locations, usage for several quarries
• Temporary mining
• Terrain leveling

During the demonstrations at Steinexpo and also thereafter production capacities between 700 and 900 tons per hour were achieved in a basalt with an uniaxial strenght of approximately 240 Mpa.

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 AMS ONLINE
www.advanced-mining.com
Sandvik’s Revolutionary Dust Suppression System gets the StBG Seal of Approval

**Sandvik Mining & Construction**

With successful installations of over 200 units throughout the world, Sandvik Mining and Construction’s electrostatic dust suppression system HX410 was recently field-tested by the Steinbruchs Be-rufsgenossenschaft – Germany’s Statutory Accident Insurance for Quarrying and Mining Industry (StBG). Using an installation at the Strobel Quarzsand facility in Freihung in Southern Germany, the HX410, which was specially developed for material transfer points in bulk-product conveying systems, was tested in a prolonged set of experiments. Findings reported by StBG showed that the HX410 substantially reduced dust particles in the air to levels well below maximum limits for both respirable and alveolar dust.

Strobel Quarzsand is a supplier of high-quality quartz sands. In Freihung, 400,000 tons of quartz sand are prepared annually for building chemicals, foundry-use, for the glass and construction industries as well as for use in sports, athletics and leisure facilities. The quartz sand is subjected to a number of different processes in order to prepare it in conformity with customers’ requirements. Despite the existence of an exhauster system, it is impossible to entirely prevent the occurrence of dust from the dried quartz-sand product at the various belt transfer points. The pulmonary, alveolar and fine quartz dusts produced constitute potentially life-threatening health hazards for the operating staff and are a burden on the environment. In addition the annual material losses at the belt transfer points are a significant cost factor. The fine quartz dust is a particular challenge to dust-suppression systems but was easily dealt with by the HX410.

The HX410 is an ionization-based system with a dust suppression rate for respirable dust greater than 90%. It is especially effective at transfer points where considerable dust from bulk material is typically released into the air. Especially benefiting from this system are bulk material transfer points in aggregates and cement, as well as foundries, and mining, steel, and glass industries. The conveyed bulk material – and with it, the dust – is routed through the housing of the dust-suppression system. The electrostatic forces acting inside the housing cause the dust to be deposited on the housing, from which it is periodically removed by means of an unbalance motor and returned to the process. The modular system is easy to install and suffers little from wear as there are no moving...
parts requiring regular service or exchange. Maintenance time is typically less than half an hour per month. It operates at high voltage (50-60 kV) and low currency (1.5 mA) so it enjoys low energy costs having a power requirement of below 0.5 kW.

Die maximale Leistungsaufnahme beträgt weniger als 0.5 kW (vergleichbar mit einer kleinen Handbohrmaschine).

The StBG reached the following conclusions as a result of these measurements: “The (mean) alveolar dust values fell from 4.25 mg/m³ to 0.56 mg/m³, while the averages for respirable dust dropped from 14.28 mg/m³ to 1.16 mg/m³”. Since the European limit for alveolar dust is 3 mg/m³, and for respirable dust it is 10 mg/m³, the HX410 system therefore brought air quality down from a level above the limit to a level far below the limit.

Within the report the Sandvik HX410 was recommended as a highly effective electrostatic dust-suppression system for bulk materials, the dust from which can be returned to the production flow. According to the policy of StBG, this would make the HX410 eligible for a 30% credit toward its purchase by the members of the StBG.

A full copy of the report can be obtained from StBG.


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www.rohstoffingenieur.de
Endress+Hauser Messtechnik GmbH+Co. KG

Solution package for the primaries sector
The tailored package of metrological solutions for bulk-solids processing industries is all you need

Endress+Hauser offer a tailored package for these industries, starting with field devices for measuring level, pressure, temperature, total flow, analysis values and for recording. The package also incorporates complete systems, including all services and automation solutions, engineering and commissioning.

Measuring bulk solids is still a challenge because the different materials place tough demands on the metrology used. Endress+Hauser offer a complete range of different measurement methods based on the diverse, physical properties of bulk solids. The solution package for the primaries sector includes the new version of the Micropilot M radar device series. With a PP horn antenna, 4 mm thick, the FMR244 is ideally suited to solids and liquid applications. All of that comes at a very attractive price. Possible applications of the FMR244 include, for example, its use in small solids silos or open bunkers with measuring ranges of up to 15 m. It has the same, menu-guided operation as the FMR250 Micropilot M to ensure easy, fast and safe commissioning.

Thanks to the enhanced hardware and software, the new 26-GHz FMR244 Micropilot M process radar device and the established FMR250 extend the possible uses of radar technology in the various applications. This is due to optimized signal analysis with the "PulseMaster eXact" software and the increased sensitivity of the high-frequency module for solids and liquid applications.

In addition to new, continuous level measuring devices, the solutions package includes the following:

- The Silopilot T electromechanical level measuring system for light bulk solids - suitable for practically all product properties (e.g. perlite, polystyrene)
- The Levelflex M guided radar with a measuring range up to 35m for powdery and fine-grained bulk solids. Not affected by dust emission or reflective surfaces (e.g. sand, sugar, grain & plastic granules)
- The Soliwave M microwave barrier with transmitter and receiver system for non-contact level limit detection in free-flowing bulk solids
- The Soliphant M vibration limit switch for fine-grained or powdery media with a bulk weight of 50g/l
- Online measurement of the mass flow rate and density with the Promass F Coriolis mass flowmeter, which has no moving parts. Suitable for dosage of liquid fuels in thermal processes in the processing of bulk solids
- The Omnigrad M temperature resistance thermometer with vibration-resistant, mineral-insulated insert, e.g. for temperature measurement of utilities such as hydraulic fluid
In addition to robust field devices for these tough conditions, solutions are also provided to cover data communication and processing of inventory data acquisition, visualization, through to inventory management. **W@M Life Cycle Management** guarantees optimal support during the entire life cycle of the field devices. W@M is an open and flexible information platform with software applications and services. It provides up-to-date and comprehensive information in relation to engineering, procurement, commissioning and also the operation, maintenance and replacement of individual components. It also provides information on products from other suppliers of instrumentation.

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**The Endress+Hauser Group**
Endress+Hauser is a global leader in measurement instrumentation, services and solutions for industrial process engineering. With over 8,000 employees worldwide, the Group generates annual net sales of more than 1.1 billion euros. Endress+Hauser provides sensors, instruments, systems and services for level, flow, pressure and temperature measurement as well as liquid analysis and data acquisition. The company supports customers with solutions and services in automation engineering, logistics and information technology. Our products set standards in quality and technology.

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Siemens AG

New AC Drive Systems for Heavy Trucks Promote Greater Productivity in Mining

Siemens announces the introduction of a new AC drive system for heavy haul trucks that offer pay-loads of 260 tons and larger. This latest generation electrical drive system reduces environmental impact, offers greater fuel economy and lowers operating costs in the mining industry. The new Siemens drive systems will be used first to power the newly announced Komatsu 860E-1K truck with other development projects planned for the future.

After successfully testing the prototype systems in the harsh mining environments of Arizona and South Africa, Siemens and Komatsu are ramping up production for early 2009 to meet market demand. The 860E-1K electric drive rigid frame dump truck’s engine was designed to be Tier 2 certified to reduce emissions. By offering a factory installed trolley-capable system option, mining operations can save fuel and prolong the life of the truck’s motor. The trolley system can be used on either 1,600 or 1,800 volt lines that enable the trucks to propel uphill faster while the engine RPM lowers, saving fuel and extending the life of the engine.

Specifically developed for the rugged demands of the mining industry, the new drive system has been designed to withstand a higher vibration and altitude spectrum and offer a temperature spectrum from -40 to 60 degrees centigrade. The innovative, liquid-cooled AC-drive system helps users achieve high productivity while lowering operating costs through its exceptional performance, efficiency and reliability. AC drives offer many advantages over traditional DC drives. Unlike DC drives, they have no brushes or commutators that require maintenance and wear out. Siemens’ Insulated Gate Bipolar Transistor (IGBT) inverter technology converts the alternator power first to DC and then to variable frequency AC for the wheel motors.

“With ‘Siemens inside’ the new truck generations improve productivity in mining,” said Dietmar Juerges,
head of Siemens Mining Technologies worldwide. “As one of the largest global providers of electrical solutions, Siemens has worked extensively with the world’s leading mining heavy equipment manufacturers, such as Komatsu, to provide innovative, reliable and efficient technologies. Our technologies are matched only by our global support that ensures users have the best products and services available anywhere in the world.”

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Volvo Construction Equipment’s L220F Hybrid wheel loader will offer significant fuel and cost saving benefits as well as performance and environmental gains when deliveries begin late next year.

Volvo Construction Equipment (Volvo CE) used the CON-EXPO-CON/AGG exhibition, held March 11 – 15, 2008, in Las Vegas to unveil a pre-production prototype of its L220F Hybrid wheel loader. Offering more power, better performance and a 10% reduction in fuel consumption, the L220F Hybrid’s increased efficiency and cost saving potential will offer customers a much greater return on their investment over the lifecycle of the machine.

Leveraging its position as the world’s largest manufacturer of heavy-duty diesel engines in the 9 – 18-liter class, the Volvo L220F Hybrid’s parallel hybrid technology has been developed within the Volvo Group and uses as its platform the proven and reliable D12 engine. While much of the technology remains confidential, subject to patents pending, the heart of the hybrid system is an ISG – Integrated Starter Generator. Fitted between the engine and the transmission, the ISG is coupled to a state-of-the-art battery that has many times the power capacity of a normal lead acid battery. The ISG works in a number of ways:

**Power when you need it – and only when you need it**

Firstly, up to 40% of a wheel loader’s time can be spent with the engine idling. The ISG allows the diesel engine to be turned off when stationary – and then almost instantly restarted by rapidly spinning the engine up to optimum working speed using a burst of energy from the high power battery.

Secondly, the ISG can also overcome diesel engine’s traditional problem of low torque at low engine speeds by automatically offering a massive electric torque ‘boost’ – as the ISG’s electric motor offers torque of up to 700 Nm from standstill. Put in engine power terms – the ISG adds up to 50 kW of instant mechanical energy.

The combination of these two attributes of the ISG mean that the diesel engine will remain off for long periods when it would otherwise be idling – and that the operator does not need to over-rev the engine in order to get sufficient torque to work, as peak torque will be offered at almost
tick-over engine speeds. The battery is then replenished automatically without reducing productivity, with the ISG acting as a dynamo/alternator.

While the ISG is the heart of the system, there are other energy saving innovations in the L220F Hybrid, such an electrically powered climate control system (rather than being powered directly by the engine). When coupled to the non-hybrid L220Fs already efficient V-ACT Volvo engine and hydraulic systems, the L220F Hybrid’s additions make for dramatic improvements in efficiency and economy without a reduction in reliability.

The best of both worlds

The Volvo L220F Hybrid will be Volvo’s – and probably the industry’s – first commercially available wheel loader when deliveries begin in late 2009. This first-generation machine will spearhead a sea change in the industry, highlighting to customers that buying hybrids offers much more than ‘just’ environmental benefits. The key advantages of the Volvo Hybrid system is that of much lower fuel costs combined with improved performance. Volvo hybrid equipment will come to be recognised as truly the best of both worlds.

More productivity and lower fuel consumption without sacrificing any of the values associated with Volvo in terms of quality and safety. The Volvo L220F Hybrid means higher efficiency and reduced fuel consumption and reduced impact on the environment.
allmineral forges ahead in iron ore beneficiation in Indian markets
yet another big contract for Indian Steel Company Jindal Steel & Power Ltd.

Together with Indian partner Hari Maschines Ltd, allmineral has managed to convince yet another major Indian company of the quality and performance of the »made in Duisburg« processing plants. Jindal Steel & Power Limited (JSPL) has ordered a total of 14 machines to expand an exiting site for haematite iron ore beneficiation in the Sarda Mines in the Indian province Orissa.

Eleven air-pulsed alljig jigging machines and four gaustec-3600 magnetic separators will allow JSPL to process low grade iron ores into products with high iron content suitable for the market. In the 1500 t/h plant in the »Sarda Mines«, five alljig G-2200 and six alljig F-2500 will be used to process grain sizes between 5 to 30 and 1 to 5 millimetres respectively. The gaustec magnetic separators with a throughput of 200 tonnes per hour each will upgrade the material with a grain size below one millimetre.

The plant expansion should be completed third quarter 2009. In this project also, allmineral will be working together with Hari Machines Ltd.: the Indian partner will manufacture the 14 units while allmineral will supply core components from Germany.

»We were involved in the process development from the start on and developed the concept for the new plant together with the client based on numerous pilot tests«, allmineral CEO Dr. Ing. Heribert Breuer said. Two issues were critical for JSPL: to set up a beneficiation plant with a maximised product yield and to not only produce products with high iron content but also those with reduced Al2O3 content. The rejects from the jigs and the first WHIMS stage will be reprocessed in the next sorting step after recrushing resp. regrinding.

The Lump and Sinterfeed products will serve the Jindal blast furnace plants. The concentrate with a grain size of less than one millimetre, after further grinding (< 40µm), will be used on site in a 4-million tpa pellet plant, which is under construction. Depending on feed quality, the total production for the plant will be between 8 and 9 million tonnes per year.

The modernisation of the plant in the »Sarda Mines« is part of a multi-billion investment programme with which JSPL is expanding the capacity of its steel plants, power stations and mines. The company, which was founded in the early 1950s, has an annual turnover of about 4 billion USD, is the third-largest steel producer in India. JSPL mines coal and iron ore in India, the USA, Indonesia and, soon, also in Bolivia. It operates power stations and produces a wide range of steel products. The company employs some 20,000 staff around the world.
The seventh international trade fair “Steinexpo” was held from 3rd to 6th September 2008 in Europe’s biggest basalt quarry in Niederofleiden, near the city of Frankfurt in Germany. A particular feature of this fair is the fact, that the exhibitors have the chance to present their machines and plants in real-life conditions of a quarry. The main processes of raw materials production and processing were demonstrated through a series of equipments. Example of equipment, which was demonstrated live in the event are: wheel loaders, hydraulic excavators, dumpers, dump trucks, mobile crushers and screens, as well as continuous miners.

This year the practice-oriented concept of the “Steinexpo” again managed to bring together numerous exhibitors and trade visitors for the three days of the fair. Altogether approximately 250 companies displayed their products and the number of trade visitors amounted to approx 42,280.

In order to assess recognition of and feedback to this year’s “Steinexpo”, AMS–Online has interviewed three internationally active companies. Mr. Wilfried Tschisch, President of Komatsu Deutschland GmbH, Mr. Roland Redlich, Chief of Product Management of Cat–Zeppelin Construction Machines and Mr. Thorsten Stellmacher, Division Manager Crushing and Screening technique of Metso Minerals, responded to questions regarding the quality of the “Steinexpo” and its trade visitors, and came up with recommendations for future improvement of the exhibition.
The Steinexpo from the Point of View of the Industry

At the heart of the Komatsu product development is the sustainable cost-effectiveness in using equipment in quarries. Komatsu company is not only focusing on the amount invested in equipment, but also on the long-term reduction of the operating costs. Moreover, our clients expect from us high-quality maintenance and service, as well as a guaranteed residual value. The Komatsu strategy is in offering the client a comprehensive solution that integrates all mining processes, from loosening to loading, transporting, to the point of dump management. For Komatsu, this would mean, for example, the system chain wheel loader/excavator with dumper and bulldozer.

As this exhibition is unique in its kind in the world, we would recommend to the exhibition management to put more effort in publicizing the exhibition internationally. This would mean more of advertisement and publicity not only in neighboring countries, but also internationally.

Wilfried Tschich, President of Komatsu Deutschland GmbH

“The visitors of this year’s “Steinexpo” had a high technical level. Many top-decision makers, owners, businessmen and other decision-makers have visited the exhibition. The visitors were mainly businessmen from Germany, but also came from Switzerland, Austria, Hungary and the Baltic states.

Our expectations have been exceeded, both in terms of the numbers of visitors, as well as in terms of the concentration of visitors at the Komatsu booth. We have concluded concrete businesses and aimed at several projects. We have had very stimulating discussions, not least because of the accompanying demonstration of the equipment, and our customers show great interest in all our machines. We are convinced that concrete projects will result from many of the discussions, which will lead to business transactions after the exhibition. Altogether the willingness of customers’ investments is very high.
"This year, after a 9-year gap, Cat has again participated in the “Steinexpo”. The trade visitors showed great interest, and we have had many positive technical discussions. The trend towards the presence of international visitors was clearly felt, a fact which is also observed in “Bauma” exhibition. The characteristic of this exhibition, an active presentation of equipment, is according to the request from the trade visitors. This enables us to present innovative approaches in optimizing our machinery to our costumers in a live manner.

In the presentations during the exhibition, the Cat strategy of offering harmonizing systems in the giant equipment sector can be realized. Cat systems are coordinated, in order to ensure optimum operation. In addition to that, for many years Cat has been offering an experienced team, which does field application consultancies, i.e. the team analyses the operation before the investment and works on improvement approaches for selection and dimensioning of mobile equipment.

Moreover, in this year’s “Steinexpo”, Cat presented innovations for increasing the operational safety during usage of mobile equipment. The trend to increased occupational safety, which recently is also evident in smaller enterprises, has been addressed and presented by Cat Company, for example through constructive optimization of trucks. The trucks used to have ladders for the driver to climb up into the driving cab. However, since studies have shown that 75% of accidents occur during ascend and descend of the trucks, the trucks are now equipped with stairs. Although it certainly has not been our primary goal, and despite the decline in willingness to invest, we have concluded businesses during the “Steinexpo”.

Concerted machine systems mark the strategy of Zeppelin and Terex | O&K in order to guarantee an optimal operation. This was demonstrated impressively by the machines at the steinexpo exhibition.
Thorsten Stellmacher, Division Manager Crushing and Screening technique of Metso Minerals

The “Steinexpo” is an ideal exhibition for Metso Minerals, as it witnesses a concentration of professional competence in the non-metallic mineral processing industry, both on the side of the exhibitors, as well as visitors.

Metso Minerals has held talks with 70-80% of its clients in the course of 4 days. Metso Minerals has not only deepened its relations to existing clients, but has also managed to obtain new ones.

The emphasis of our participation in the exhibition was on demonstrating new equipment, which shortens the production chain and leads to saving one crushing step, while at the same time maintaining the quality of the products. This is a technical innovation of the Metso Minerals Company, which leads to a sustainable reduction of costs. These innovations are in line with the goals of our clients, particularly in the non-metallic mineral processing industry, who only invest in the case there is a reduction of costs or an improvement in quality. As an example we have followed our slogan of “achieving more with less” and developed our HP4/5 crushers, a product that increases the output while at the same time improving the quality of the product.

At the “Steinexpo” we have had many technical discussions with clients from east Europe on upcoming investments in large plants. Since we have a strong presence in these countries, there is a good possibility to implement projects with clients in these countries.

Metso Minerals took a positive balance of this years Steinexpo and took the opportunity to unveil new products from their broad range of processing machines.
## 2009
### The AMS-Event Calendar

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<tr>
<td>01 - 02 Jan</td>
<td>MINEX 2009</td>
<td>Izmir, Turkey</td>
<td><a href="http://www.izfas.com.tr">www.izfas.com.tr</a></td>
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<td>18 - 20 Jan</td>
<td>MENA-EX 2009</td>
<td>Jeddah, Saudi Arabia</td>
<td><a href="http://www.mena-ex.com">www.mena-ex.com</a></td>
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<td>09 - 12 Feb</td>
<td>Mining Indaba 2009</td>
<td>Cape Town, South Africa</td>
<td><a href="http://www.miningindaba.com">www.miningindaba.com</a></td>
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<td>15 - 18 Feb</td>
<td>STONETECH 2009</td>
<td>Shanghai, China</td>
<td><a href="http://www.stonetech.merebo.com">www.stonetech.merebo.com</a></td>
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<tr>
<td>24 - 27 Feb</td>
<td>Techno+Stone 5th International Exhibition</td>
<td>Kiev, Ukraine</td>
<td><a href="http://www.kievbuild.com">www.kievbuild.com</a></td>
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<tr>
<td>09 - 12 Feb</td>
<td>Mining Indaba 2009</td>
<td>Cape Town, South Africa</td>
<td><a href="http://www.miningindaba.com">www.miningindaba.com</a></td>
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<td>15 - 18 Feb</td>
<td>Lehrgang für Fach- und Führungskräfte in der mineralischen Rohstoffindustrie</td>
<td>Clausthal, Germany</td>
<td><a href="http://www.bergbau.tu-clausthal.de">www.bergbau.tu-clausthal.de</a></td>
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<td>23 - 27 Mar</td>
<td>Asia Mining Congress 2009</td>
<td>Singapore</td>
<td><a href="http://www.terrapinn.com">www.terrapinn.com</a></td>
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<tr>
<td>25 - 28 Mar</td>
<td>MAWEV SHOW 2009</td>
<td>Kottingbrunn, Austria</td>
<td><a href="http://www.maweve-show.at">www.maweve-show.at</a></td>
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<td>15 - 17 Apr</td>
<td>MiningWorld Russia</td>
<td>Moscow, Russia</td>
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<td>14 May 2009</td>
<td>Braunkehlentag 2009</td>
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<td><a href="http://www.debriv.de">www.debriv.de</a></td>
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<td>20 - 23 May</td>
<td>Stone+Tec</td>
<td>Nuremberg, Germany</td>
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<tr>
<td>02 - 06 Jun</td>
<td>CTT Moscow 2008 – 10th International Exhibition of Construction Equipment and Technolog</td>
<td>Moscow, Russia</td>
<td><a href="http://www.ctt-moscow.com">www.ctt-moscow.com</a></td>
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<tr>
<td>03 - 06 Jun</td>
<td>UGOL ROSSI &amp; MINING 2009</td>
<td>Novokuznetsk, Russia</td>
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<td>18 - 19 Jun</td>
<td>Mining 2009 – Clausthaler Kongress für Bergbau &amp; Rohstoffe</td>
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<td>28 Jun – 01 Jul</td>
<td>EMC 2009 – 5th European Metallurgical Conference</td>
<td>Innsbruck, Austria</td>
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<td>16 – 18 Sept</td>
<td>MiningWorld Asia</td>
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<td>06 – 08 Oct</td>
<td>MiningWorld Uzbekistan</td>
<td>Tashkent, Uzbekistan</td>
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