PROJECT X-MINE: REAL-TIME MINERAL X-RAY ANALYSIS FOR EFFICIENT AND SUSTAINABLE MINING

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ПРОЕКТ X-MINE: НОВА СЕНЗОРНА ТЕХНОЛОГИЯ ЗА УСТОЙЧИВ ДОБИВ

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РЕЗЮМЕ

„Асарел-Медет" е единствената българска компания, която е част от мащабния изследователски проект X-Mine, координиран от VTT - Център за технически изследвания на Финландия. Международният консорциум за иновации обединява научни институти, производители на оборудване и минни компании от различни европейски страни. Екипът на X-Mine разработва нови сензорни технологии за геоложко проучване и внедрява дигитални продукти за моделиране на находищата и по-ефективна преработката на рудите.

Новите сензорни технологии са на базата на рентгенова флуоресценция (XRF), рентгенова трансмисия (XRT) и триизмерни технологии за визуализиране. Всички те се интегрират с оборудване за сортиране на минералите, заедно със софтуерни системи за моделиране на рудните находища и за планиране на минното производство.

Новите технологии бяха пилотно внедрени в четири минни компании в Швеция и Гърция през 2018 г., а през тази година това се случи в Кипър и България, където партньор е „Асарел-Медет". Очаква се минните компании да постигнат до 20% намаление на транспортните разходи, 7% намаление на преработената откривка, от 10 до 30% по-ниско потребление на енергия и намаление на въглеродните емисии. Плановете предвиждат комерсиализирането на продуктите да стане до две години след приключването на проекта, когато и други и компании ще имат достъп до X-Mine.

Изследователският проект X-Mine има общ бюджет от 12 милиона евро и е финансиран по програмата на Европейската комисия „Хоризонт 2020". Счита се, че в дългосрочен план новите методи ще доведат до революция в проучването и характеризирането на съществуващите и нови находища, защото ще оптимизират цялата верига на стойността на минните операции. Чрез тях още при геоложкото проучване ще се знае размерът на минералните зърна, разпространението им и цялата необходима структурна, геоложка, геохимична и минералогична информация. Така добивът не само ще стане по-ефективен, но също ще се намали въздействието върху околната среда. Сред големите предимства е, че ще има по-малко отпадъци и по-точен избор на местата за добивни дейности. Наред с това ще има спад на използваната енергия, транспортните разходи и въглеродните емисии. Проектът X-Mine ще направи разработването на по-малки и сложни находища икономически осъществимо и потенциално ще увеличи европейските минерални ресурси. Същевременно при него се залагат високи стандарти за опазване на околната среда и устойчиво развитие на минния добив.

The X-Mine innovation project has a total budget of 12 million Euro and it is funded under the Horizon 2020 program of the European Commission. It develops new geological exploration and ore sorting sensor technologies and implements digital applications for deposit modelling and more efficient ore processing.

The pilot implementations are done in four European countries, Sweden, Greece, Cyprus and Bulgaria.

The new sensor technologies are based on X-ray fluorescence (XRF), X-ray transmission (XRT) and 3D visualization technologies. They are incorporated in mineral sorting equipment and drill core scanners and the results are applied through specialized software for assessment and analysis to ore deposit modelling and mining operations planning.

It is believed that in the long-term the new methods will revolutionize the exploration and characterization of existing and new deposits, since they will optimize the entire value chain of mining operations. By applying these methods, the mineral grain size, their distribution and the entire structural, geological, geochemical and mineralogical information will become known even at the geological exploration stage. Thus, mining will not only become more efficient, but the environmental impact will also be reduced. One of its significant advantages is that less mining waste will be generated and mining locations will be more accurately selected. Simultaneously, the consumed electric power, transportation costs and carbon emissions will be reduced. The X-Mine project will make the development of smaller and complex deposits feasible from economic perspective and will potentially increase the European mineral resources. High environmental protection and mining sustainable development standards are set in it as well.

Assarel-Medet JSC Mining and Processing Complex is the first and largest Bulgarian company for open pit mining and processing of copper ore, providing around 50 % of the national production of this vital metal. It is also the only Bulgarian company, which forms part of the large-scale research X-Mine project. Thanks to the X-Mine project, the mining companies, including Assarel-Medet JSC, are anticipated to achieve reduction of their transportation costs, waste, carbon emissions and lower power consumption.

Experiments have been performed at Assarel-Medet JSC with two pilots – a drill core scanner during the last year and with a sorter since March 2021.

The Assarel mine is located near the town of Panagyurishte in west-central Bulgaria, about 75 km east of Sofia (Figure 1). The deposit was discovered in 1967 and mining has been ongoing there since 1976. A pre-mining and non-regulatory compliant resource estimate for Assarel is c. 354 million tonnes (Mt) of ore grading 0.44 wt.% Cu and 0.2 g/t Au . These tonnage-grade values make Assarel the largest known porphyry Cu deposit in Bulgaria and the fourth largest in the Carpathian-Balkan tract after comparable deposits in Romania and Serbia (e.g., Moldova Nouă and Majdanpek, respectively. Current annual production at Assarel is c. 13 Mt of ore yielding approximately 180 000 tonnes of Cu concentrate, which represents about 50% of Bulgaria's annual copper output. Mining at Assarel is performed by open-pit surface methods typical for large tonnage, porphyry-type Cu ± Mo ± Au deposits. Presently, the pit has a bowl-like form measuring approximately c. 2.5 x 2.0 km and a depth of c. 550 m.

The Assarel deposit is situated in the Panagyurishte ore district of west-central Bulgaria (Figure 1). The district forms part of the southeast (Srednogorie) segment of the larger Apuseni-Banat-Timok-Srednogorie (ABTS) magmatic-metallogenic belt, a Late Cretaceous tec-tonothermal zone that extends in a curving "L"-shape from Romania in the north to SE Bulgar-ia. The ABTS belt, in turn, forms part of the western end of the Tethyan (or Alpine-Himalayan) orogen stretching from the Alps to SE Asia. This intercontinental orogen formed episodically in response to closure of the Paleotethys and Neotethys oceanic basins in the Paleozoic and Mesozoic, respectively, and has continued to evolve in Europe as part of the Alpine collision zone . In Bulgaria (Figure 1, inset map), the Srednogorie (or Sredna Gora) unit forms part of a collage of Neoproterozoic-Mesozoic lithotectonic zones that partly comprise the broader Carpathian-Balkan and Serbo-Macedonian mountain belts. Cretaceous arc magmatism, sedi-mentation, and strike-slip deformation developed in the Srednogorie zone during northward subduction of the Neotethys (Vardar) ocean beneath the Eurasian (Moesian) continental margin. Post-arc shortening and oroclinal buckling subsequently occurred during the Cenozoic.

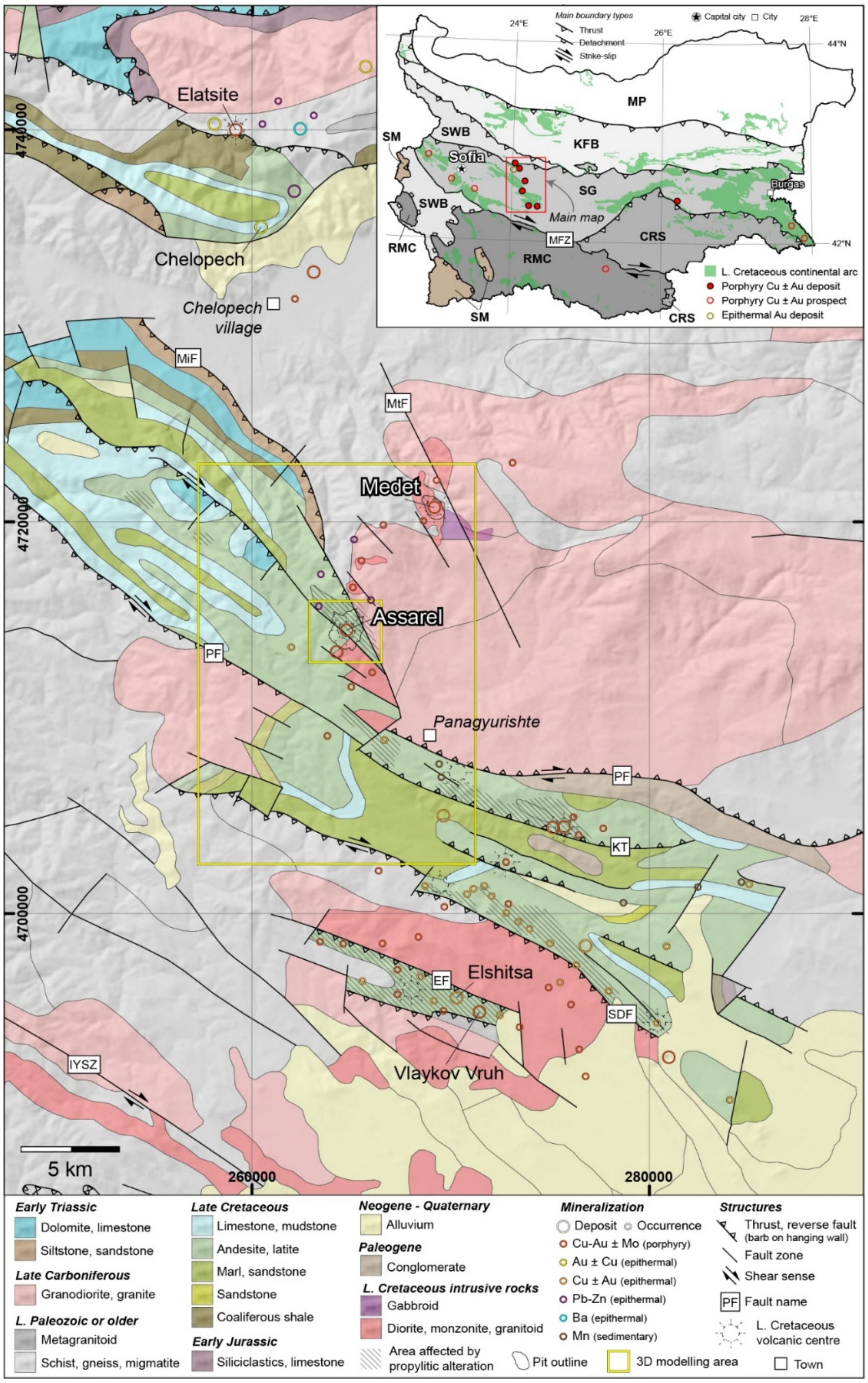

Figure 1 Geological setting of the Assarel Cu-Au deposit, Panagyurishte ore district, Bulgaria.

Along the ABTS belt, numerous porphyry Cu ± Au ± Mo, high-sulfidation epithermal (HSE) Au ± Cu ± Ag, volcanic-hosted Pb-Zn, and polymetallic skarn Fe deposits occur. Mineralization is attributed to Late Cretaceous arc magmatism that produced mainly intermediate (andesitic, dioritic), calc-alkaline volcanic-plutonic complexes, transcurrent deformation, and concomitant magmatic-hydrothermal activity. Within this framework, a relatively short lived (c. 8 - 10 million year) Turonian-Santonian metallogenic epoch developed in the central Srednogorie (Panagyurishte) area, producing the Elatsite, Medet, Assarel and Vlaykov Vruh porphyry Cu ± Au ± Mo deposits, and several HSE deposits and prospects (e.g., Chelopech; Figures 1 and 2;. Geochronology and tracer isotope data suggests porphyry and HSE mineralization in the Panagyurishte district is progressively younger from north to south (c. 92 – 84 Ma; Figure 2), while coeval magmatic rocks record an increasing degree of mantle wedge influence in the same direction. These effects are attributed to the southward retreat or roll-back of the Vardar oceanic slab as Late Cretaceous subduction progressed.

The oldest rocks in the Panagyurishte area are ortho- and paragneiss, and subordinate schist and amphibolite that form part of the northern margin of the Rhodope Metamorphic Complex (RMC) (Figures 1 and 2. The RMC represents a composite Neoproterozoic – Lower Paleozoic continental terrane that was affected by subsequent Variscan- and Alpine-cycle tectonothermal events. These included nappe stack thrusting and subduction-related UHP metamorphism in the Jurassic – Cretaceous, and post-orogenic core complex exhumation in the Late Eocene - Oligocene. Plutonic rocks belonging to the Carboniferous Srednogorie (South Bulgarian) granitoid suite also form a basement unit in the Panagyurishte area (Figures 1 and 2). These intrusions typically comprise coarse to megacrystic granodiorite to granite (sensu stricto) with locally occurring pegmatitic veins, dykes and mafic mi-crogranular enclaves. Srednogorie granitoids were emplaced in the RMC during the Carbonif-erous Variscan orogeny and represent a phase of collisional to post-collisional magmatism associated with crustal shortening and amphibolite-facies metamorphism. In the Medet area, gabbroic-dioritic rocks (part of the Smilovene igneous complex) are also linked to Variscan-cycle orogenic events and intrude the metamorphic basement. Early to Middle Triassic si-liciclastic rocks (e.g., Petrohan-Iskar terrigenous group, Bosnek formation) and Early to Middle Jurassic carbonate rocks (West Balkan carbonate group) occur as volumetrically minor units in the study area and represent episodes of fluvial-alluvial and shallow marine sedimentation (Figures 1 and 2).

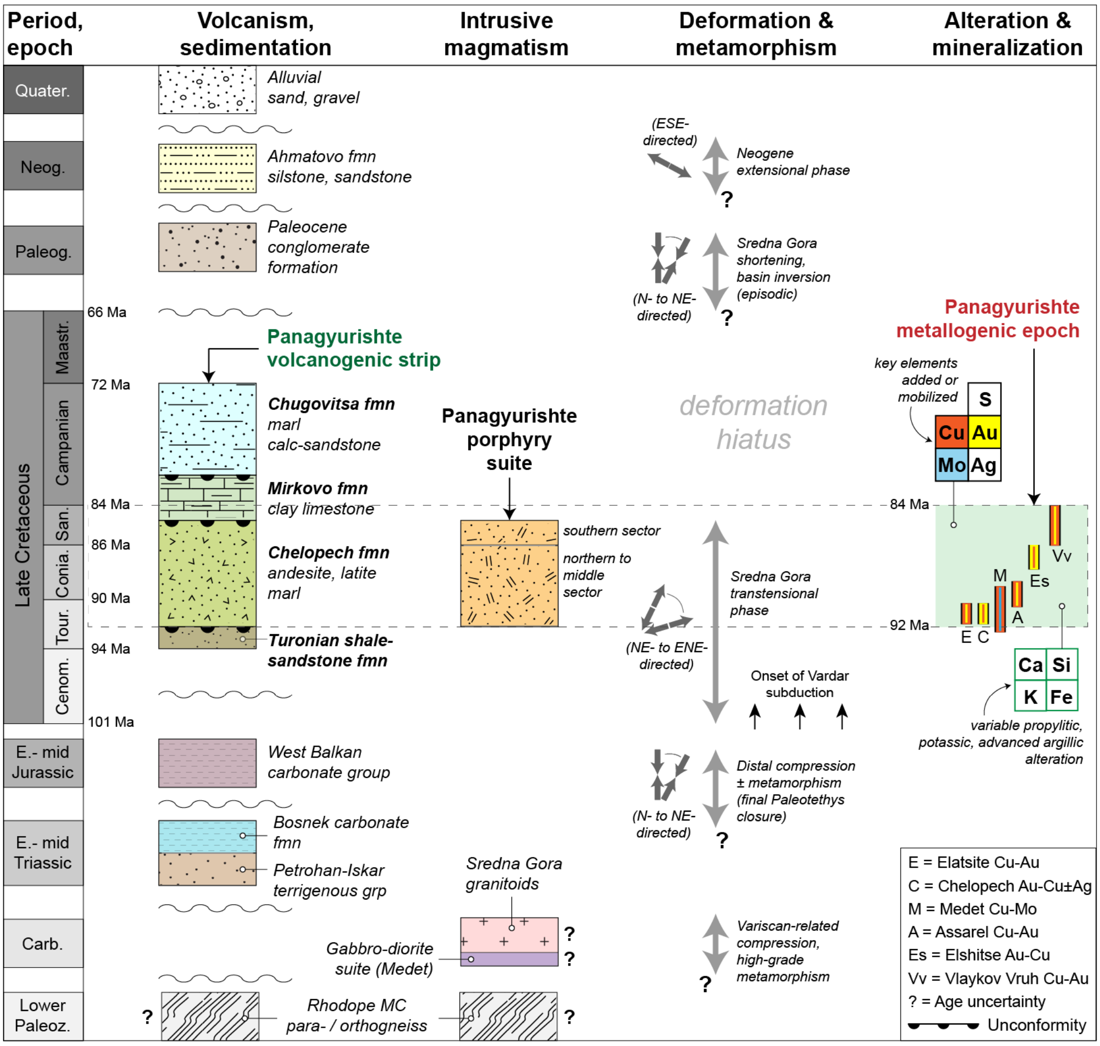

Figure 2. Temporal framework for major geological events in the Panagyurishte ore district.

Late Cretaceous (Turonian-Campanian) volcanic, subvolcanic, and sedimentary rocks constitute a major lithotectonic unit in the Panagyurishte area (Figure 1). Combined, these rocks form a fault-bounded, c. NW-SE-aligned volcanic-sedimentary strip comprising basal sandstones and coaliferous shales (Turonian terrigenous formation), calcalkaline inter-mediate volcanic rocks (Chelopech formation), and overlying limestones, sandstones, and marls (Mirkovo and Chugovitsa formations; Figures 1 and 2;. Geological contacts between the major formational units are generally non-conformable and tectonic. Dioritic to granitic intrusive bodies (Panagyurishte porphyry suite in Figure 2) were emplaced within and adjacent to the volcanogenic sequence along a regional c. NNW-SSE trend and are co-magmatic with Chelopech formation andesite-latite volcanic rocks. These commonly porphyritic intrusions are representative of the causative magmatism associated with porphyry and HSE Cu-Au mineralization across the district, including that at Assarel and Medet.

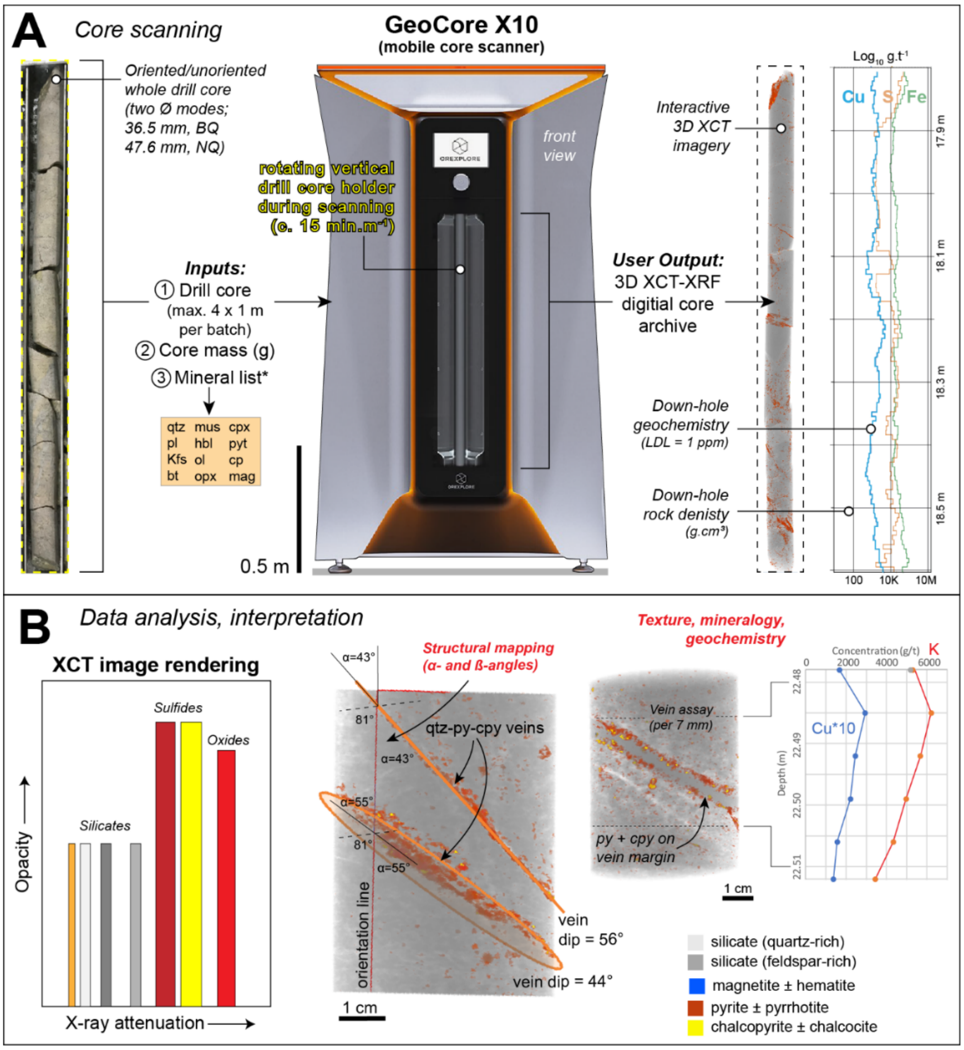

Figure 3. Summary of the GeoCore X10 (GX10) scanning instrument and its use. (A) Overview of scan-ning process: Whole, cylindrical drill core (BQ up to NQ2) is loaded into the scanner using a central, vertical carousel system that holds up to 4 x 1 m-long core sample tubes. Following depth information input, scanning proceeds at a max. rate of c. 15 min. per metre during which time the core is weighted and an XRF sensor scans the rotating core. A site-specific, pre-determined mineral list comprising end-member mineral compositions and densities is used as input to XRF chemical analyses, and rock density estimates. The user output is a 3D digital archive of downhole XCT images, XRF geochemical and rock density data; (B) Summary of post-scanning data analysis and interpretation. Rendering of 3D XCT images (by adjusting opacity and relative at-tenuation parameters) allows detailed textural and mineralogical information to be identified. 3D XCT core segments.

Structurally, the Panagyurishte area is dominated by WNW- to NW-trending, moderately to steeply dipping oblique-reverse fault zones (e.g., San Dere fault, Figure 1), and similar-ly trending, sub-horizontal and overturned folds. A subordinate set of c. NE-SW-oriented fault zones also occurs, while the distribution of known porphyry and HSE deposits occur along a c. NNW-oriented magmatic-metallogenic tract. In general, these structures record a phase of Paleogene crustal shortening and basin inversion that was likely accommodated by reactivat-ed extensional faults originally formed during Late Cretaceous (i.e., syn-mineralization), mainly dextral transtensional deformation. The youngest rocks in the Panagyurishte area are minor, isolated occurrences of Paleogene-Neogene sedimentary rocks (e.g., Ahmatovo sandstone formation) and Quaternary alluvial deposits (Figures 1 and 2).

As part of the X-MINE project, four subvertical and oriented diamond drillholes (XM001 – XM004) were drilled during autumn 2019 at Assarel. The holes were collared in the east-central part of the open pit at mine level +675 m, along a c. NNE-SSW profile approximately 60 m apart. The project drillholes intersect the Assarel Cu ore body and contain mineralization and alteration features inferred to be representative of the deeper parts of the porphyry system. The drill core scanner (Figure 3) is used for collecting indicative geochemical data and tomographic imagery for structural identification, annotation and documentation.

The results from the scanning of drill core is stored on a dedicated SAN (Storage Area Network) server for scanned results and is batch wise downloaded to transportable 1 to 4 TB external hard drives. The scan results are available via the site's internal network and are studied with the Insight software installed on laptops.

The goals of the tests in Assarel-Medet with the sorter are to sort the ore piles from the ballmill crushing of the processing plant. The main aims are to get rid of as much of the waste rock but save the valuable copper bearing minerals.

The mobile sorting equipment is shown in Figure 4. The sorting unit is placed inside the container which is equipped with necessary inlet and outlet windows for introducing feed material and discharging separated fractions. The container has an additional compartment as a control room where a main control cabinet and an air-conditioning equipment are placed. The control room and some electronic components of the sorting unit are equipped with the necessary heating and cooling devices for controlling a temperature during operation independently from outside weather conditions. The fed material is sent to the sorting unit through the upper window to the vibrating feeder. The feeder distributes the processed material on the whole width of the feeding chute and forms the material into a mono-layer of particles. The distributed material is further accelerated on the sliding plate to reach a speed of the conveyor belt in the central part of the sorter. The material further passes through the X-ray gate where the sensing equipment is installed. In addition, the 3D camera is planned to be placed over the belt to provide information about optical properties of the sorted material including particle shape. After the X-ray and optical images are analysed, the decision is made in the control unit and the chosen particles are rejected by air nozzles providing short pneumatic pulses at the discharge area of the belt. This results in physical separation of the rejected and non-rejected fractions. These fractions fall down to the short horizontal conveyors under the container and they are further transported by the regular conveying equipment to the separate bins or piles.

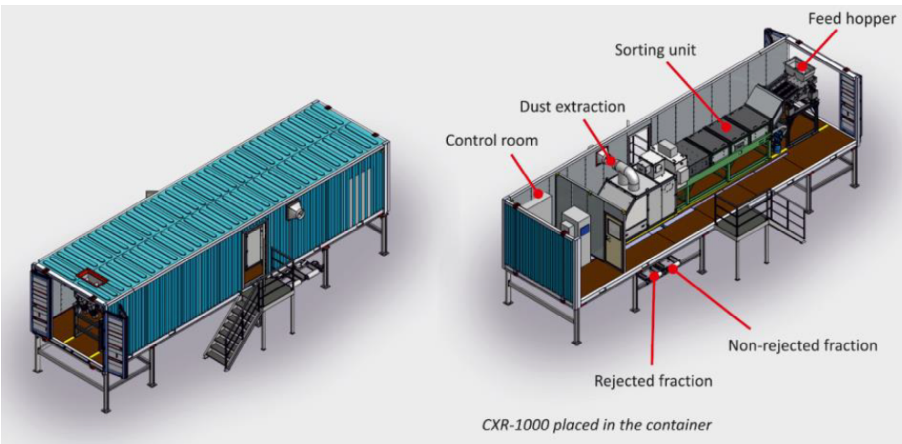

Figure 4. Illustration of the sorting equipment placement inside the container.

The X-ray gate is equipped with the XRT sensors based on DE (dual energy) analysis. These sensors are placed in the sealed metal compartment, for easy replacement when other sensor types are to be tested or investigated. The X-mine sensors (high resolution) were aimed to be tested in this configuration by replacing the sensor compartments and rearranging the electronic communication devices. The control unit is based on an industrial PC with necessary auxiliary equipment like uninterruptible power supply (UPS), VSD for sorter motors, and general process automation components. The air nozzle control is realized by a separate FPGA based electronic unit to provide high precision of particle rejection in a very strict time regime.