Environmental Impact Statement (EIS) report from Global Sea Mineral Resources (GSR) project.

a Executive summary

Global Sea Mineral Resources (GSR) developed a pre-prototype collector vehicle (PPV) equipped with a launch and recovery system to be deployed and trailed in the GSR contract area of the Clarion-Clipperton Fracture Zone (CCFZ) in the NE Pacific Ocean. The present Environmental Impact Statement (EIS) is built in the framework of two distinct projects: the ProCat#2 project (technical validation of the design of a PPV) and the JPI-OII MiningImpact2 program (evaluation of environmental impacts in the CCFZ). During the trial, nodules will be collected from a small area of seafloor (ca. 0.1 km2) at a water depth of ca. 4400 m, over 4 days. The technological objectives are to validate the maneuverability, reliability and nodule pick-up efficiency of the 4 m-wide PPV, and analyze potential environmental impacts. The scientific objectives are to assess potential environmental impacts from the potential future nodule mining operation on the seafloor. The JPI-OII MiningImpact2 program is a consortium of 31 partner institutions (from science and industry) from 9 European countries. It aims at developing, standardizing and testing monitoring concepts and strategies. It also aims at investigating the short- and medium-term potential environmental impacts of nodule collection, in order to propose potential mitigation measures and the development of spatial management plans and to develop adapted methodologies to asses' risks, benefits and uncertainties to be implemented in future regulations and guidelines. The JPI-OII MiningImpact2 program focusses on 3 major research topics: (1) the potential large-scale environmental impact caused by a suspend sediment plume, (2) the regional connectivity of species and the biodiversity of biological assemblages and their resilience to impacts and (3) the integrated effects of disturbances on ecosystems and their functions (benthic food web and biogeochemical processes). Using an integrated 3D hydrodynamic and sediment transport model, the distance that the suspended plume in the water column is likely to have after 4 days of testing could vary from few kilometers to up to 12 km (depending on the current conditions at the seafloor). The monitoring survey will take place in the area of direct impact (nodule removal), in the area of plume deposition and in a non-impact reference site. This survey will be adapted/refined prior to testing, according to refinements of models and/or collection of new baseline data. The plume monitoring results will be used to validate the sediment transport numerical model. The JPI-OII MiningImpact2 program will organize, facilitate and manage the archival of generated environmental data and samples in databases.

b Review/comment and questions

Introduction chapter. The JPI-OII MiningImpact2 program will be conducted within the GSR contract area. Similar experiments and monitoring program will be also conducted within the contract area of the BGR (Federal institute of Geosciences and Natural Resources, in Hannover, Germany). The present Environmental Impact Statement (EIS) is related to a technical project (Procat#2) and a scientific project (JPI-O MiningImpact2 environmental project) proposed by the GSR.

Within the frame of Procat#2 technical project, and after maneuverability tests in soils, the PPV needs to be tested *in situ*. The nodule collection mechanism of the PPV has been already tested in a laboratory. The aim of Procat#2 is to develop a system economically viable with limited impacts on the environment. *In situ* tests of the PPV aims at validating its maneuverability, reliability and nodule collection efficiency as part of an overall mining system as well as analyzing environmental impacts, in order to validate the engineering design.

The aim of JPI-O MiningImpact2 environmental project, is to gather data on operational impacts and develop precautionary approach for future potential mining plan. GSR is not part of the scientific consortium analyzing and monitoring the environmental impacts from the R/V SONNE. This is providing a transparent, objective, collaborative, adaptive and effective approach to the development and testing of mining technology.

The project JPI-O MiningImpact2 is structured in several work packages (WP) and cross-cutting themes (CCT). WP1 focus on biodiversity, connectivity and resilience of the abyssal environment to disturbances arising from mining operations. WP2 aims at understanding the impact and behavior of the sediment plume. WP3 will provide a better understanding of benthic ecosystem functions. WP4 will facilitate data exchange and archival storage for the project. In CCT1, effective monitoring data will be integrated in CCT2 to synthetize scientific results into an assessment of environmental impacts and to develop recommendations on risks and best-practices of deep sea-mining operations (CCT3). Finally, WP5 will coordinate the project, communicate and disseminate project results.

This report is a detailed description of the technology tested in the framework of a scientific project. Because no specific requirements are available, GSR has taken the approach to follow the best practices of other industries, such as the offshore dredging industry, where applicable. Because these tests are planned in a limited area for a limited period (4 to 5 days) and are not including transport and commercial or industrial developments, socio-economic considerations are not included in this EIS report. The benefit for the contractor, sponsoring state (Belgium) and stakeholder community consists of advances in deep sea science and environmental management knowledge related to potential future polymetallic nodule mining in the CCFZ.

Project description chapter. The purpose of GSR is to test the PPV in the GSR contract area in the CCFZ. The GSR contract area (76,728 km^2) is divided into 3 domains (B2, B4 and B6) located between 122 and 128°W and 13 and 15°N in the CCFZ. The test area (B4 domain, 0.1 km^2) is chosen because the environmental baseline is more complete and more suitable for potential future mining projects. In this area the Remus 6000 Automatic Underwater Vehicle (AUV) was used and AUV data is in particular available and could be very useful to establish environmental baseline (see below).

The test area surface (Impact Reference Zone, IRZ) will depend on the speed of the PPV. One of the key questions of this project is to establish what will be the Plume Impact Reference Zone (PIRZ). A Control Reference Zone (RZ) is located far from the planed activity of the PPV and where geophysical, biological and chemical features comparable to the affected area are available. In Figure 4 (page 28), it is indicated that the AUV Remus 6000 was equipped with an OmniTech Parametric sub-bottom profiler (10-60 kHz), but no data are presented or detailed in this report. This acoustic device could, however, provide important information from the deep sea sediments architecture and help establishing what are the quality and characteristics of IRZ, PIRZ and RZ. In Figure 5 (page 35) sub-bottom profiler data are not documented neither while it could be used as base line before the tests and key to compare the state of deep sea sediments after the tests, but also provide key data to validate sediment plume model results after the tests.

Mineral resource estimation chapter: In B4 domain a model has been developed to build up a resource estimation using seafloor photogrammetry using high-resolution (small scale) data collected from Remus 6000 AUV and from geophysical data collected from a surface vessel (large scale/low resolution). Resource estimation from AUV track lines were extrapolated to the sub-zone and then to the full GSR contract area. Because soil tests revealed that slope accessible to the PPV should be less than 15%, these areas where mapped and excluded from the area assessments. Nodule coverage was modeled by correlating picture analysis results (slope, backscatter data and Benthic Terrain Model (BTM)) from first classification model in areas with or without many nodules. Box core sampling data was used to validate the models. It is clear that bathymetry and backscatter data are key parameters for nodule size and concentration estimations. We don't know however how the BTM is established and if it contains information on sediments geometries in the sub-surface using high-resolution seismic reflection data. If not why not using such acoustic sub-bottom data? Preliminary results from geochemical analyses of sediment samples suggest that the major elements found in nodules (Mn, Fe, Ni, Cu, Ca) are present at nearby constant concentrations between box core samples. Nodule in B4 are mainly of the diagenetic type (Mn/Fe ratio>5).

Pre-Prototype collector Vehicle (PPV) description and design chapter. The so-called *PATANIA II* PPV contains a nodule collection system, a propulsion system, a nodule separation and discharge system and vehicle systems. The depth of influence of the PPV in the sediment is difficult to predict and we don't know how the seabed will be affected by the hydraulic lift collector (nodule collection system). This device is assumed to perturb surface sediments down to ca. 5 to 15 cm below seafloor, but this depth is depending on the thickness of unconsolidated top layer of the seabed. We don't know if multicore data are available in the IRZ, PIRZ and RZ, but such type of undisturbed sediment samples would help estimating the thickness of unconsolidated top layer of the seabed and thus the impact of nodule collection by the PPV at the seafloor. The PPV is 4m wide, 6m long and contains 2 caterpillars for displacement (each caterpillar track is expended to be 1.5m wide and 12 cm deep at the seafloor). Approximately 3 mT of nodules can be stored inside the container and will be dumped outside the Direct Impact Area every 50 to 150 m (depending on nodule concentration at the seafloor).

Geomorphological settings chapter. Bathymetric, side scan sonar data, and AUV pictures allow establishing a detailed morphology of the study area.(Figure 27, p 66) and a detailed geomorphological map is given based on AUV data set, but sub-bottom profile data from the OmniTech Parametric sub-bottom profiler (10-60 kHz) installed the AUV are not presented. These acoustic data could be very useful to document the variability of sediment thickness below the sea floor and could thus provide a key base line for sediment geometry before and after the test of the PPV and the collection of nodules. This type if acoustic mapping could also be useful to map (after the PPV tests) the plume deposits link to nodule collection and thus help testing/validating sediment plume modelling (see below). In this report we only know that a variable thickness of the sediment layer is related to "sediment transport phenomena"…

Detailed oceanographic data are presented and illustrating good quality available data on currents in the GSR area. It is important to note that current eddies are present in the BGR area, but not in the GSR area. Currents in the GSR area vary between 2 to 15 cm/s. Tidal energy was also observed for the last 10 m of the water column above the seabed. Hydrodynamic model TELEMAC-3D data were also compared to available mooring data in the GSR area (mean current velocity, standard variation and mean direction). Model time series includes periods that are consistent with the short-term current measurements only. The model validation will be extended further once the results from long-term mooring measurements are available.

The prevailing natural sedimentation rate is thought to be only few millimeters per 1000 years in the abyssal habitat, but not supported by radionuclide or radiocarbon data. Sedimentary facies and upper sediment layer subdivision (extracted from box-cores) are however precisely exposed and illustrated. Computer Tomography (CT) scanning in most sediment cores allow illustrating with great details burrowing intensity and revealed a clear boundary at the first 2-10 cm of sediment. Multi-sensor core logger (MSCL) data show that most of the cores are characterized by low magnetic susceptibility and low wet-bulk density values at the top of the core and are both quickly increasing until reaching a maximum typically at 3-5 cm deep. This suggests the presence of a regional hiatus in the GSR area. Smear slide analysis of sediment sample revealed that it contains ca. 40 % of biogenic silica. Bulk grain size measurements highlight that the muddy and silty components of the sediments are corresponding to the biogenic portion (but down core variability can perhaps be attributed to bottom current variations in the past, bioturbation and/or early diagenesis). XRF analysis shows the presence of enriched layers. The Ca/Si, Si/Al and Mn/Fe ratios show the most relevant variations and are frequently associated with changes in sediment color. Clay mineralogy (smectite, illite, kaolinite and chlorite) is suggesting that the deep sea sediment origin is probably essentially continental. Finally, geotechnical sediment characteristics is documented based on undrained shear strength measurements reviling 0kPa at the surface up to a maximum value of 9.5 kPa in the lower part of the box core sample (20-25 cm deep). Superficial sediments are in addition rich in water and thus very easily removable.

Description of existing biological environment chapter. The test area is characterized by heterogeneous environments with gradual changes of conditions such as nodule size and densities, differences in surface productivity and depths. *Key conclusions are that deep sea ecosystems associated with polymetallic nodules support a highly diverse fauna*. Deep sea faunal communities are characterized by a high variability on both small and large spatial zones and *their connectivity remains unknown*. In order to be able to make rigorous statements about differences in environmental and faunal parameters between different habitats or periods, replication of samples is paramount.

Description of Natural Hazards chapter. Volcanism is considered highly unlikely (*but no convincing arguments are given*), no data on recent seismic activity is available and the occurrence of benthic storms at the seafloor is considered as unlikely (since water is clear above the seafloor and no mud is found on nodules). *The potential impact of tsunami waves are not considered here while this is clearly asked in the Annex V given by the ISA*. *If it is very unlikely that tsunami waves could impact the planned test in the GSR area (at the sea surface and at the seafloor), their potential impacts at the seafloor in the study area should be considered if large scale mining activities are planned.(such surface waves are known to be erosive even at large water depths because they have large wave lengths and very high speed and for example at an ocean depth of 4000 m the tsunami waves travel at about 700km/h, i.e. the speed of a plane)*

Assessment of impacts and proposed mitigation chapter. The potential impact categories associated with the planned test of the PPV are listed and consisting in: habitat/nodule removal; sediment disturbance and plume formation, biochemical alteration of the sediment, potential release of potentially toxic sediments and /or substances into the lower water column and potential additional impacts from natural hazards such as hurricanes or benthic storms. At the moment, the amount of sediment deposition from a mining-induced plume that could either be tolerable or lethal for any of the faunal groups of the deep sea is unknown.

Sediment transport modelling is detailed in p133. The numerical model used had a limited calibration for hydrodynamics and is not yet calibrated for sediment transport. Therefore the findings presented in this reports are preliminary results. A separate model is used to resolve the dispersion of the released sediments in the vicinity of the vehicle (the near field is about 100 to 200 m downstream, depending on the dynamics) in order to simulate the turbulent flow responsible for the dispersion of sediments in the direct vicinity of PPV. Here the discussion is limited to the obtained vertical profiles of sediment concentration at a distance of 150 m behind the PPV at work. Vertical profiles of sediment flux are transferred to the source terms of the far-field plume dispersion model. This revealed that the PPV operations will form a density current. A sediment plume 3 to 5 m high is modelled (with the majority of sediment flux occurring within the 2m above seabed). At the boundary between near-field and far-field model, the density current is less turbulent and might be re-suspended by the ambient flows. Four different scenarios were considered with different trajectory, sediment flux and activity cycle of PPV. No sediment deposition is observed in the reference area during any of the scenarios. Areas of 1 mm deposition (1 to 2.5 km2) and of 0.1 mm deposition (4 to 9 km2) are estimated. The horizontal extent of the sediment plume is estimated between 5 to 12 km. Vertical extents of the sediment plume would be between 20 to 120 m above the seafloor*. It is however surprising that modelled sediment blanketing (using the same PPV and similar operations) results are very different from modelling results in the BGR area. It is also surprising that, similarly to the BGR project, this GSR project is limiting sediment plume modelling to the PPV test only, and not simulating the potential impacts of full-size mining operations. In the BGR area preliminary results are suggesting the possible generation of sediment blanketing reaching several meters at significant distance from the operating nodule collector vehicle. Another surprising aspect of the sediment plume GSR modeling is that flocculation process is not at all considered, while BSR modeling suggests this process might be very important and could result in much thicker sediment blanketing. GSR modeling is only used to estimate impact of PPV tests (with a limited size of vehicle collecting nodule) and only considering 4 scenarios with different PPV operations, but without considering flocculation processes in the sediment plume and without clearly contrasted current conditions.*

Modern instrumentation on biogeochemical alterations (ROV-targeted sampling and in situ sensors) is needed for precise characterization of the nature and intensity of impacts and to address their biogeochemical consequences. Molecular tools for the characterization of microbial communities are needed. Investigation have shown that even a few decades after disturbance, the geochemical composition and redox-layering of surface sediments in disturbed areas are still strongly altered, whereas pore waters seem to equilibrate much faster. Baseline conditions are needed in order to identify mining-related effects and to assess their significance in relation to naturally occurring temporal and spatial variations in the benthic boundary layer. Many geochemical and biogeochemical parameters showed an unexpectedly high degree of spatial variability, suggesting the need to thorough characterization of baseline conditions. Biochemical impacts are specific to the particular nature and intensity of the physical impact (with strongest effects observed in regions where the surface layer of sediment with labile organic matter was lost and deeper sediment layers were exposed). Stiffer and less porous sediments appear to be more difficult to recolonize by bioturbating organisms that mix in fresh organic matter. All these processes are thus unfavorable for re-establishing stable biogeochemical conditions and processes.

Impacts on the biological environment chapter. The expected impacts of nodule collection activities are: habitat/nodule removal, sediment disturbance and plume deposition, concentration of plume particles in the water column above seafloor, biogeochemical alterations of the sediment, potential release of toxic sediments and/or substances into the lower water column.

Accidental events and natural hazards chapter: Tropical cyclones are considered but with minor consequences for the planned activities and tests. Emergency procedures in case of accidental events seem adapted in case of emergency recovery (A frame failure, cursor system failure, lift wire winch failure, umbilical winch failure or internal failure, surface hydraulic power unit failure).

Organization within JPI-MinignImpact 2 consortium chapter. Planed organization and activities are sounds. *Several up to date technics are planned to better understand deep-sea environments and habitats*. An advanced geotechnical device (Graviprobe) is planned in situ to document compaction effects on physical properties and pore-water expulsion in the sediments due to PPV operations. *These data are necessary in order to better understand variability and changes in static bearing strength of the sediments*. These in situ measurements will be compared to shear strength measurements in experiment laboratory. *These informations are needed to estimate the impact of nodule collection on the deep-sea environment*. Assessments of sedimentation and bioturbation dynamics are also considered and will be based on Computed tomography (CT scan) of collected sediment cores. A suite of radionuclide measurements are also planned to document sedimentation mode and rate.

Onsite pre-impact assessment will include sediment sampling to determine baseline sedimentological, geochemical and biological conditions. Multicores collection, video-surveying, deployments of moorings and sediment traps will be necessary to measure background particles fluxes in the water column and to better contribute to predictive models for the dispersion of the sediment plume. Since thickness of sediment blanketing resulting from the PPV test are expected to be limited, changes in multi-beam backscatter intensity will be used to quantify the impact of nodule collection. *As mentioned above, it is however surprising that flocculation processes are not included in sediment plume dynamics. In the BGR area, flocculation processes are considered important and are included in sediment plume modeling. The GSR sediment plume modelling is thus not very convincing.*

c List of recommendations

Description of high-resolution seismic profiles collected from the AUV are needed in the study area and should be used to precisely map deep sea deposits before and after the tests and in order to validate sediment plume modelling. Sediment plume modelling should include flocculation processes and consider different scenarios depending not only on PPV activities but also on variable current conditions. Modelling the impact of full size mining activities would also be necessary. The potential impact of tsunami waves at the seafloor is not considered during the test of the PPV, but it should be addressed if full-size mining activities are planned. This is particularly necessary if large scale mining would generate large volume of sediment blanketing at the sea floor. Tsunamis are surface waves known to be erosive even at large water depths because they have (very) large wave lengths and very high speed. For example at an ocean depth of 4000 m the tsunami waves travel at about 700km/h, i.e. the speed of a plane. Such a catastrophic event could have problematic cumulative effects on regional biogeochemical processes at the seafloor. If such a tsunami is unlikely to occur during the 4 days of nodule collector vehicle test, the potential impact of tsunami waves should be explored by available modelling tools and applied on sediment blanketing deposits modelled following large scale mining activities.

d Concluding findings and remarks of the EIS

This EIS report is generally accurate and providing an up to date understanding of available technology and potential environmental impacts of nodule collector vehicle tests in the GSR license area of the CCZ. Accurate maps are given and advanced tools are used to better understand deep sea environments. Methods and technics planned to monitor the environmental impacts are sounds. Sediment plume modelling is not very convincing and should include flocculation processes but also scenarios considering full size mining activities in order to plan an adapted suite of technics to measure the impact of nodule collection at the seafloor. Sub-bottom profiling from AUV should be presented and used to validate geomorphological maps and sediment plume modeling data. The latter should consider the potential impact of tsunami waves at the sea floor on dispersal of sediment blanketing since this could have dramatic cumulative effects on regional biogeochemical processes at the seafloor.