Working Group on Seafloor Massive Sulfides (SMS)
Resource along Mid Ocean Ridges (MOR)

Final Report for InterRidge Workshop on Hydrothermal Ore-forming Processes and the Fate of Seafloor Massive Sulfides Deposits along Slow and Ultraslow Spreading Mid-Ocean Ridges

Hangzhou, China

September 19th – 22nd, 2019

Recent surveys suggest that slow and ultraslow spreading ridges have an excess of high temperature venting relative to their predicted magmatic and mid-ocean ridge (MOR) spreading heat budgets. Despite these recent discoveries, the occurrence, distribution pattern, formation mechanism, and resource potential of hydrothermal systems on a global scale remains poorly documented and defined. In this context, the InterRidge Working Group (WG) on Seafloor Massive Sulfide (SMS) deposits along MOR convened this workshop aiming to capture the known/unknown BIG questions on SMS formation, distribution and preservation in the geologic record and to identify future ways to address the questions. The workshop was organized by WG Chair Prof. Chunhui Tao (Second Institute of Oceanography – Hangzhou, China) and Co-Chairs Prof. Georgy Cherkashov (Institute for Geology and Mineral Resources of the Ocean – VNIIO, Russia) and Prof. Maurice Tivey (Woods Hole Oceanographic Institution, WHOI, USA). Chair of InterRidge, Prof. Jerome Dyment, Director of SIO, Academician Jiabiao Li, and Director of COMRA, Mr. Feng Liu served as Honorary Chairs for this workshop.

The workshop was held over three days at Hangzhou, China. More

than 150 SMS related scientists and students from worldwide participated in this workshop. For the 1st day, eleven SMS related experts shared their results through the Primary Session after which all attendees were divided into three breakout groups to brainstorm the BIG questions existing in the SMS formation, distribution and preservation. For the 2nd day, eight young scientists presented their work at the Early Career Scientist Session, followed by a poster session. In the afternoon, all attendees were divided into three groups again to discuss the way forward to address the BIG questions and these discussions were summarized in a plenary session at the end.

Breakout discussions

Attendees were randomly assigned to each of the three breakout groups. Two members each from the WG were solicited as discussion leaders for the Breakout Groups. These were Bramley Murton and John Jamieson for Breakout Group 1, Sven Peterson and Desiree Roerdink for Breakout Group 2 and Isobel Yeo and Amy Gartman for Breakout Group 3. The breakout groups addressed outstanding questions and potential solutions and approaches in three broad subject areas, i.e., **(1) formation of SMS deposits, (2) distribution of SMS deposits and (3) preservation of SMS deposits.**

In ***Breakout Group 1***, on questions **on the formation of SMS deposits**

the participants suggested that a big question was how much mineralization may be occurring sub-seafloor. They also raised questions on the role of brines or physical and chemical traps for creating deposits. It was agreed that collaboration is the most important approach to tackling these questions and that the community needs to share ideas, methodologies and techniques. Of these, sharing research infrastructure (i.e., ship time, vehicles, and instruments) is key in order to make significant advances in this area. They also agreed that multi-disciplinary segment scale studies are needed to characterize the physical and geochemical footprints associated with both surface and buried SMS deposits. **On the distribution of SMS deposits**, they considered the strategies and efficiency of exploration. The following questions were raised. **First**, are comprehensive segment-scale mapping approaches the most effective method for efficient exploration? **Second**, what new areas of the seafloor should be focused on, e.g., off-axis exhumed crust along axial valley faults, seamounts, etc…? **Third**, what physical properties can be used to distinguish SMS deposits? The participants suggested that segment scale surveys should include components of orthogonal, off-axis surveys that cross geological features. A temporal component to ridge processes is increasingly seen as important, especially for the study of extinct and buried deposits. Instead of focusing primarily on studying the SMS deposits themselves, the focus should include studies of sediments

(drilling, gravity coring, etc…), which act as a record of surface geological (and biological, and oceanographic) processes along spreading ridges. **On the preservation of SMS deposits**, there are questions about the frequency of deposits and how are they preserved. Again, the key is the sedimentary record. Sediment can record distal signatures of present and past hydrothermal activity and can therefore provide an important vectoring tool for SMS deposits. It was suggested that the IODP program has an extensive core repository and associated metadata that may contain significant information related to hydrothermal activity in different ocean basins. It was noted that most of the past studies involving these cores likely did not focus on hydrothermal activity. Therefore, there may be a significant amount of relevant information stored in these cores and associated data.

In ***Breakout Group 2,*** the participants also considered lots of questions on the ***formation of SMS deposits***. These questions can be divided into three parts. First, what are the time intervals of hydrothermal activity (geochronology)? Is there a link between magma supply and deposit formation and size? By extension, where are the big SMS deposits (compared to VMS)? Second, there should be attention paid to the role of microbial life in deposit formation and sediments as a caprock and in the formation of replacement deposits. Third, it was suggested that the metal fluxes (at segment scale) and transport in fluids (e.g., nanoparticles

colloidal metals, organic ligands) deserve much more attention. The remobilization from previous deposits (i.e. zone refining) is also very important. **On the distribution of SMS deposits** questions were raised on the distribution of SMS in space and time and in 3D, if there was a spreading rate dependency to frequency of occurrence and where are the big deposits? On the question of **preservation of SMS deposits**, timescales of rates of oxidation, microbial activity and tectonic and volcanic dismembering were discussed. Does size matter and what is the oldest deposit we can expect to find and where?

To address these questions it was suggested that drilling is key to determining the size, thickness, and metal distribution in SMS deposits. One wish is for a seafloor drill rig that is capable of routinely drilling to 50 m depth and that it can overcome the issues of low recovery. Meanwhile, mapping or geophysical surveys at some distance from the ridge axis (>30 km?) should be undertaken to identify the off-axis distribution of SMS in space, time and 3-D structure. It was suggested that long range AUVs capable of multi-beam mapping (plus low-energy sensors such as magnetics and SP) should be used to enhance exploration. Finally, it was suggested that systematic gravity coring off-axis may help to identify the oldest SMS and resolve the issues regarding SMS preservation. It would be useful to measure temperature during gravity coring.

In ***Breakout Group 3,*** the participants addressed three major issues **on the formation of SMS deposits**. First, there were questions about the connection between the frequency of plumes and the frequency of SMS deposits. Why do some plume-influenced ridges seem not to be hydrothermally active? Do we understand the tectonic settings that we are looking for? Second, there are questions about what conditions form the largest/highest grade deposits. Third, questions were raised about the mineralization process e.g., what happens to chalcophile elements during mineralization? Are seafloor deposits only mineralized by primary fluids? How variable is the solubility of elements with depth? It was suggested that promoting exploration on specific settings are required, e.g., subduction/spreading interactions, oceanic core complexes (OCCs) sediment filled regions (Escanaba, Red Sea). Also, regions that have long histories of venting (i.e., are very active) should be targeted. As for the mineralization process, it was suggested using knowledge of element behavior on land to better constrain how these elements work in SMS deposits. However, experimental studies are still required to constrain their chemical behavior. **On the distribution of SMS deposits**, the following questions were raised. How far off axis should we go? Can we better define weathering timescales to predict the furthest reaches worth exploring? Systematic coring off axis is recommended for detecting signatures of hydrothermal activity, e.g., hydrothermal signatures have

been detected in sediments near Semenyov, MAR. In addition, as noted above, regions that have long histories of venting should be investigated and regions off axis should be targeted in an attempt to identify old deposits (using morphology, backscatter, and sampling). **On the preservation of SMS deposits,** the following questions were raised. How quickly are sulfides weathered at the seafloor? Are the deposits refining or losing elements through oxidation? What is the role of microbes during oxidation? Tectonic influences must also be considered e.g., are deposits tectonically disassembled as they are rifted out of the valley? Are detachment faults better at preservation because the deposit is rafted out of the valley whole? It was suggested that dating deposits is required to investigate weathering processes. It was agreed that the complete hydrothermal footprint including the sediments should be sampled and analyzed. Systematic exploration can be conducted from active sites (e.g., possibly TAG). Are there older core complexes identified in the geologic seafloor spreading record to target? It was noted that investigations don't have to go "big" right away - incremental advances on what we know are also valuable.

For more details of the individual breakout group discussions see the bulletined lists in the appendix. All attendees agreed that the in-depth discussion promoted their understanding of the current situation of the SMS related subjects. At the internal round-table conference, the WG

summarized the output of this workshop, exchanged ideas for potential international cooperation and initially planned to hold the 2nd workshop in Russia, 2020.

Excellent Early Career Scientist in SMS Award

To further encourage young scientists to carry out SMS related research, the WG decided to select one excellent early career scientist from worldwide to grant him/her the **Excellent Early Career Scientist in SMS Award** at the next workshop in 2020. See Appendix 4 for more details.

Acknowledgements

The participants thank support for this workshop from InterRidge, China Ocean Mineral Resources R & D Association (COMRA) and National Key R & D Project of "Penetrating the hydrothermal circulation system along ultra-slow spreading Mid-Ocean Ridges". In particular, the WG thanks the Second Institute of Oceanography (SIO) for kindly hosting this workshop.

Workshop Agenda

Listed below are presentations from Primary Session, Early Career Scientist Session and Poster Session.

Primary Session

Geological mapping of mid-ocean ridges and its implications and use for the prediction of SMS occurrences - Sven Petersen

An integrated assessment extinct Seafloor Massive Sulphide deposits at the TAG hydrothermal Field - Bramley Murton

Oceanic Core Complexes and the substrate for formation seafloor hydrothermal sulphide deposits - Henry J.B. Dick

The inactive hydrothermal vent fields in the Central Indian Ridge between 8°S and 18°S, Indian Ocean - Sang-Joon Pak

Hull-mounted multibeam echosounder (MBSE): a cost and time-effective tool for detection of extinct seafloor massive sulfide deposits - Ewan Pelleter

Diversity of hydrothermal systems on Southwest Indian Ridge - Chunhui Tao

All SMS deposits are hydrothermal deposits, but not all hydrothermal deposits are SMS deposits - John Jamieson

Extreme hydrothermal activity on Carlsberg Ridge during the last glacial stage: evidence from an off-axis sediment core - Xiqiu Han

Finding, mapping and evaluating seafloor mining prospects - Isobel Yeo

Can submarine massive sulphide deposits be recycled? - Fernando Barriga

Morphology and formation of SMS deposits in different geological settings - Georgy Cherkashov

Early Career Scientist Session

3D Seismic Imaging and Potential Massive Sulfides Deposits of Geolin Mounds Hydrothermal Field in the Southern Okinawa Trough - Ho Han Hsu

Ultramafic rocks hosting sulfide mineralization along SWIR: insights from the sulfide sulfur isotopic and LA-ICP-MS trace-element composition - Teng Ding

Au and Te Minerals in Seafloor Massive Sulphides from Semyenov-2 Hydrothermal Field, Mid-Atlantic Ridge - Anna Firstova

Difference in hydrothermal activity between slow and fast spreading centers - Duo Zhou

Multi-stage detachment faulting controls hydrothermal activity in the Dragon Horn area (49.7°E, SWIR): Insight from magnetic studies - Tao Wu

Numerical simulation of hydrothermal plumes in stratified crossflows - Yingzhong Lou

Poster Presentations

Uranium in seafloor massive sulfides at the Mid-Atlantic Ridge (MAR) - Anna Sukhanova

The Daxi Vent Field on the Slow-Spreading Carlsberg Ridge: An Active Hydrothermal System at a Non-transform Offset - Yejian Wang

Hydrothermal Fe-Mn deposits from low-temperature systems of the Mid-Atlantic Ridge - Pedro Costa

The characteristic of the Mid-Atlantic Ridge between Hayes and Kane Fracture Zone - Michal Tomczak

Stepwise hydrothermal dissolution of titanomagnetite dramatically reduces magnetization in basaltic ocean crust: direct evidence from the Southwest Indian Ridge - Shishun Wang

Surface sediment geochemistry and hydrothermal activity indicators in the Dragon Horn area on the Southwest Indian Ridge - Shili Liao

Bulk geochemistry, sulfur isotope characteristics of the Yuhuang-1 hydrothermal field on the ultraslow-spreading Southwest Indian Ridge - Shili Liao

Surface sediment composition and distribution of hydrothermal derived elements at the Duanqiao-1 field, Southwest Indian Ridge - Shili Liao

Seismic observations of an active detachment faulting system beneath the Longqi hydrothermal field at the ultraslow spreading Southwest Indian

Ridge - Yunlong Liu

Diversity of metal sources for sulfides in hydrothermal fields in the Southwest Indian Ridge - Chuanwei Zhu

Hydrothermal fields in the southern Okinawa Trough off northeastern Taiwan - Song-Chuen Chen

Can Magnetites Provide New Information about the Physical and Chemical Conditions inside Hydrothermal Vents? - Sang-Mook Lee

Highly siderophile elements and Osmium isotopes in abyssal peridotites from the Southwest Indian Ridge: Implications for evolution of the oceanic upper mantle - Wei Li

A Quantitative Method for Active Fault Migration Distance Assessment on Both Sides of the Southwest Indian Ridge 46°～52.5°E—Based on Multi-Beam Data - Bo Feng

Crustal Thickness Anomalies Across the Carlsberg Ridge in the Northwest Indian Ocean Basin From Gravity Analysis - Juechen Song

Geological mapping at Southwest Indian Ridge Qiaoyue Seamount (~52°10′E）： Implication for prediction of hydrothermal field - Yongjin Huang

Synthetical anomaly characteristics of the 26th segment of Southwest Indian Ridge and implications for submarine hydrothermal activity - Zhen Dong

Mineralogy and sulfur isotope characteristics of chimneys from Wocan-1

hydrothermal field, Carlsberg Ridge - Yiyang Cai

Mineralogical in mafic and ultramafic rocks from the substrate of the Tianxiu Hydrothermal Field, Carlsberg Ridge - Peng Zhou

Sedimentary Records of Hydrothermal Activities at Tianxiu Hydrothermal Field, Carlsberg Ridge -Mou Li

Exploring the role of microorganisms in sulfur deposition in hydrothermal environment via metagenomic data mining - Baowei Huang

Geochemistry of hydrothermal fluids from Carlsberg Ridge – Xueting Wu

Metal stable isotopes as tracers to constrain hydrothermal ore-forming processes - Yunchao Shu

Geological characteristics and delineation of hydrothermal anomalies around 55°20′E of Southwest Indian Ridge - Liang Huang

Traceability Analysis of Seafloor Sediments Based on ArcGIS and Its Application in the Longqi Hydrothermal Field on the Southwest Indian Ridge - Donglei Pan

APPENDIX – 1

Breakout Session 1: BIG Questions on Formation, Distribution and Preservation of SMS Deposits

Group 1 - Group leader: Bramley Murton and John Jamieson

1) Formation of SMS deposits

- How much mineralization occurs sub-seafloor? What is the role of brines or physical and chemical traps?

2) Distribution of SMS deposits

- Systematic exploration: Are comprehensive segment-scale mapping approaches the most effective method for efficient exploration?
- Should we be focusing on new areas of the seafloor, such as off-axis exhumed crust along axial valley faults, seamounts, etc…?
- What geological features should we look for in order to find the BIG deposits?
- What physical properties distinguish SMS deposits?
- Geological maps may be key: systematic sampling of sediments, fault scraps, etc…
- How can we improve survey efficiency?

3) Preservation of SMS deposits

- Off-axis regions for SMS: frequency of deposits? How are they preserved? What is the role of sediments?
- What is our depth or overburden tolerance for buried deposits?

Group 2 - Group leader: Sven Petersen and Desiree Roerdink

1) Formation of SMS deposits

- geochronology (what are the time intervals of hydrothermal activity)
- metal sources for certain metals such as tin
- role of (microbial)life in deposit formation
- why do we not find epidosites on the modern seafloor
- role of sediments as caprock or for replacement deposits
- is there a link between magma supply and deposit formation and size
- where are the big deposits (compared to vms)
- influence of permeability of the underlying crust
- what are the segment scale metal fluxes and their temporal variations (link to sea level changes??)
- are we underestimating metal transport capability for certain metals in fluids, e.g. nanoparticles colloidal metals, organic ligands
- remobilization from previous deposits (zone refining)

2) Distribution of SMS deposits

- what is the off-axis distribution of active and inactive deposits in space and time (and in 3D!!)
- spreading rate dependency

- role of transform faults
- abundance of low-T and Lost City types for fluid flow, fluxes and distribution of oasis in the deep
- where are the big deposits ?
- how does the long-term evolution of detachment faults influence deposit formation
- are metalliferous sediments an underestimated resource (Cu-rich muds at TAG!)

3) Preservation of SMS deposits

- for how long are they preserved on the seafloor? (influence of oxidation rates, microbial activity, tectonic and volcanic dismembering)
- what is the oldest age where we can still find sms deposits?
- what are the changes in metal distribution/tenor during aging of the deposit in space and time and the underlying processes
- does sixe matter for preservation?

Group 3 - Group leader: Amy Gartman and Isobel Yeo

1) Formation:

- Can serpentinization alone feed hydrothermal venting? Almost all deposits on OCCs seems to be associated with Gabbro. Unlikely we have fresh peridotites so likely magmatic sources are required.
- Sub-sea floor – many unanswered questions because we don't have enough exploration data. We need drilling on a range of deposits. How deep should we be trying to drill? Can we collect cuttings? Could give a clearer picture of the sub-seafloor given difficulty in collecting uninterrupted cores.
- How variable are temperatures at MORS? Are different ridges associated with different mantle compositions? If the mantle is depleted differently (as a result of partial melting) that may have an affect on the material harvested by hydrothermal fluids. Is there a relationship between deposit geometry and/or chemistry and mantle compositions?
- What are some deposits richer in some elements? Do we have a good understanding of why that is?
- What happens to chalcophile elements during mineralisation?
- Are seafloor deposits only mineralised by primary fluids?

- Do we find similar deposits in other geological settings? How similar are plume processes to MOR systems?
- Why do some plume influenced ridges seem not to be hydrothermally active? Do we understand the tectonic settings that we are looking for?
- Do we understand the connection between frequency of plumes and frequency of SMS deposits?
- What conditions form the largest/highest grade deposits?
- How variable is solubility of elements with depth – how shallow do you need to be before you stop precipitating metals?

2) Distribution:

- How far off axis should we go? Can we better define weathering timescales to predict the furthest reaches worth exploring? At 13N the spatial distribution of deposits is not linear – you cannot necessarily use seafloor age. Found vent systems on 50 Ma crust.
- Can you use active hydrothermal flux as a way to pinpoint deposits?

3) Preservation:

- Often speak of "resources", what constitutes a resource, particularly at inactive sites? What counts as an inactive site? Would low temperature sites be considered inactive? Should there be

classifications for inactive sites – and how do sites evolve when venting ceases?

- Can we detect to a level at which we can define whether or not a deposit is inactive? Difficult with AUV exploration – localised and low concentration. Inactive/unknown?
- How quickly are sulphides weathered at the seafloor? Are deposits tectonically disassembled as they are rifted out of the valley? Are detachment faults better at preservation because the deposit is rafted out of the valley whole?
- Do we have the right tools to find old deposits?
- Are the deposits refining or losing elements through oxidation? What is the role of microbes during oxidation?
- How different is venting at fast-spreading ridges? How variable is the frequency (relatively short lived and not a huge amount deposited). How different is ultra-slow vs. slow venting? Is ultra-slow more prospective?
- Do inactive economic deposits exist?

Which of these questions are most important?

- Detection of inactive deposits
- Aging

- What environment makes the largest/richest deposits? This would enable us to identify off-axis regions that may host deposits.

APPENDIX – 2

Breakout Session 2: How to address challenges of understanding the formation of economically interesting SMS deposits

Group 1 - Group leaders: Bramley Murton and John Jamieson

- Collaboration is key. The community needs to share ideas, methodologies and techniques. Sharing of research infrastructure (ship time, vehicles, and instruments) is key for significant advances in our field.
- Multi-disciplinary segment scale studies are needed to characterize the physical and geochemical footprints associated with both surface and buried SMS deposits.
- Segment scale surveys should include components of both traditional along-axis surveys, but orthogonal, off-axis surveys that cross the geological ridge structures and provide a temporal component to ridge processes is increasingly seen as important, especially for the study of extinct and buried deposits.
- Instead of focusing primarily on studying the SMS deposits themselves, we should focus on studies of sediments (drilling, gravity coring, etc…), which act as a record of surface geological (and

biological, and oceanographic) processes along spreading ridges. The sediments provide an important record of time, and also can record distal signatures of present and past hydrothermal activity, and can therefore provide an important vectoring tool for SMS deposits.

- The IODP program has an extensive core repository (and associated metadata) that may contain significant information related to hydrothermal activity in different ocean basins. Most of the past studies involving these cores did not focus on hydrothermal activity, therefore there may be a significant amount of relevant information stored in these cores and associated data.
- We need to focus on the balance between improving our fundamental geological understanding of these systems with the application of new exploration technology.

Group 2 - Group leaders: Sven Petersen and Desiree Roerdink

Prioritized challenges for the Working Group

1. what determines the size, thickness, and metal distribution in SMS deposits (where are the big ones?) drilling, drilling, drilling (19)

   Solution: drilling

2. what is the off-axis distribution of active and inactive deposits in space and time and 3-D (16)

   Solution: mapping or geophysical surveys at some distance to the ridge axis (>30 km??)

3. are metalliferous sediments away from the deposits) an underestimated resource? (vectors to ore!) (10)

   Solution: systematic gravity coring off-axis

4. what is the role of sediments (or other caprocks) in SMS formation (8)
5. what are the changes in metal distribution in SMS deposits through time (7)
6. how does the evolution of detachment faults influence SMS formation (6)
7. what are segment scale metal fluxes and their temporal variations (5) this is actually similar to (2)
8. for how long are SMS deposits preserved on the seafloor (5)
9. what is the oldest SMS (Sven)

Wish list:

1. drill rig capable of routinely drilling to 50m depth
2. logging while drilling to overcome loss on information due to low recovery
3. T-measurement during gravity coring
4. long range AUVs capable of multibeam mapping (plus low-energy sensors such as magnetics and SP) to enhance exploration

4)

Group 3 - Group leaders: Amy Gartman and Isobel Yeo

- Detection of inactive deposits
- Aging of inactive/waning vents
- What environment makes the largest/richest deposits?

1. Promote exploration

- Focus on specific settings that we feel are advantageous to big (high grade, high tonnage) deposits (informed by terrestrial models) e.g. subduction/spreading interactions, OCCs, sediment filled regions (Escanaba, Red Sea). Some data mining required – could use available data from transits etc to identify sites.
- We should be seeking out regions that have long histories of venting (i.e. are very active) and look at age isochrons off axis in an attempt to identify old deposits (using morphology, backscatter, sampling). Possibly TAG?
- Challenges associated with sensing hydrothermal deposits through thick sediment packages. EM? (Easier to drill).
- Not just chimneys- crusts and sediments, need to look at the whole site

- Systematic coring off axis – looking for signatures in gravity cores in sediments off axis, piston coring in deep sediments. Hydrothermal signatures have been detected in sediments near Semenyov.

- Don't have to go big right away – incremental advances on what we know are also valuable.

- Should also examine why certain segments are chronically active. Or do we have a sampling bias towards sites we have comprehensively studied? Do hydrothermally active ridges have a long history of being unusually active? Again, requires some investigation off axis to investigate longevity of geological processes that influence hydrothermal activity.

- Active examples of very active ultra-slow ridges? SWIR/CIR – at least 4 active sites known and also several inactive sites. Longqi 1 (active) – lots of sites (district), some inactive. Sits on the hanging wall but is basalt hosted. Compare to MAR example.

2. Other

- We should collect the whole hydrothermal footprint including the sediments, systematic exploration from active sites e.g. again possibly TAG? There is an identified older core complex.

- Define active vs. inactive – some deposits are active in some areas and not in others
- Consider that it doesn't need to be a single deposit, could be many smaller deposits – idea of SMS clusters/districts.
- Can we use element behaviors on land to better constrain how this works in SMS deposits? Use modelling to develop hypotheses of areas that are enriched. Need better constraints on chemical behaviors from experimental studies.
- Need to date deposits in order to investigate weathering processes.

3. Need comprehensive drilling – we do not know the tonnage accurately of almost any deposits

APPENDIX 3 – **List of Participants**

Florian Besson (IFREMER, France), Ewan Pelleter (IFREMER, France), Isabel Costa (Escola Superior Tecnologia Barreiro, Portugal), Fernando Jose Barriga (University of Lisbon, Portugal), Henry J.B. Dick (WHOI, USA), Jerome Dyment (IPGP, France), Anna Firstova (Institute for Geology and Mineral Resources of the Ocean, Russia), Anna Sukhanova (Institute for Geology and Mineral Resources of the Ocean, Russia), Amy Gartman (United States Geological Survey, USA), Agata Kozłowska-Roman (Polish Geological Institute - National Research Institute, Poland), Sang-Mook Lee (Seoul National University, South Korea), Maurice Tivey (WHOI, USA), Michal Tomczak (Polish Geological Institute - National Research Institute, Poland), Bramley Murton(National Oceanography Center, UK)，Sang-Joon Pak (Korea Institute of Ocean Science and Technology, South Korea), Sven Petersen (GEOMAR, Germany), Desiree Roerdink (University of Bergen, Norway), Cindy Lee Van Dover (Duke University, USA), Isobel Yeo (Kingston University London, UK), Chunhui Tao (SIO, China), Xianming Deng (SIO, China), Yiyang Cai (SIO, China), Yinxia Fang(SIO, China), Xiqiu Han(SIO, China), Chunhua Gu (SIO, China), Daji Huang (SIO, China), Yongjin Huang (SIO, China), Jin Liang (SIO, China), Shili Liao (SIO, China), Yunlong Liu (SIO, China), Jia Liu (SIO, China), Honglei Shen (SIO,

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Appendix 4 –

Excellent Early Career Scientist in SMS Award

1. General info and selection criteria for this award after the ISA guideline
   - One person every year from worldwide
   - In early 5 years of his/her scientific research career after PhD or master.
   - Have achieved a significant contribution to advance scientific knowledge of SMS related discipline
   - Nomination deadline: **April 30th, 2020**
   - Send the material to wg_smsmor@sio.org.cn with subject of "Excellent Early Career Scientist in SMS Award + Name + Affiliation", for example: Excellent Early Career Scientist in SMS Award, Thomas Zhang, Zhejiang University, China
2. Nominations should consist of the following documents
   - A letter from the nominator summarizing the research of the applicant and outlining the national or international significance of the applicants work to date. The letter should not exceed 750 words;
   - The curriculum vitae of the candidate;
   - Any relevant publication derived from the applicants.

— Two letters of sponsors outlining the type and impact of the research carried out by the nominee.

3. Advisory Committee
   — All WG members; However,
   — Members are required to disclose any conflict of interest and to recuse themselves from evaluating any proposal on which they have or may be perceived to have a conflict of interest such as having a mentor-mentee relationship with the candidate.
4. Selection Process
   — Members of the Advisory Committee evaluate and sort the applications. The evaluations will be submitted to Co-Chairs for the final decision.
5. Award and Presentation
   — An award will be granted to the successful applicant.
   — The awardee will be announced at the next WG meeting or will be announced through the InterRidge and/or WG channel.