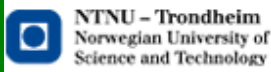
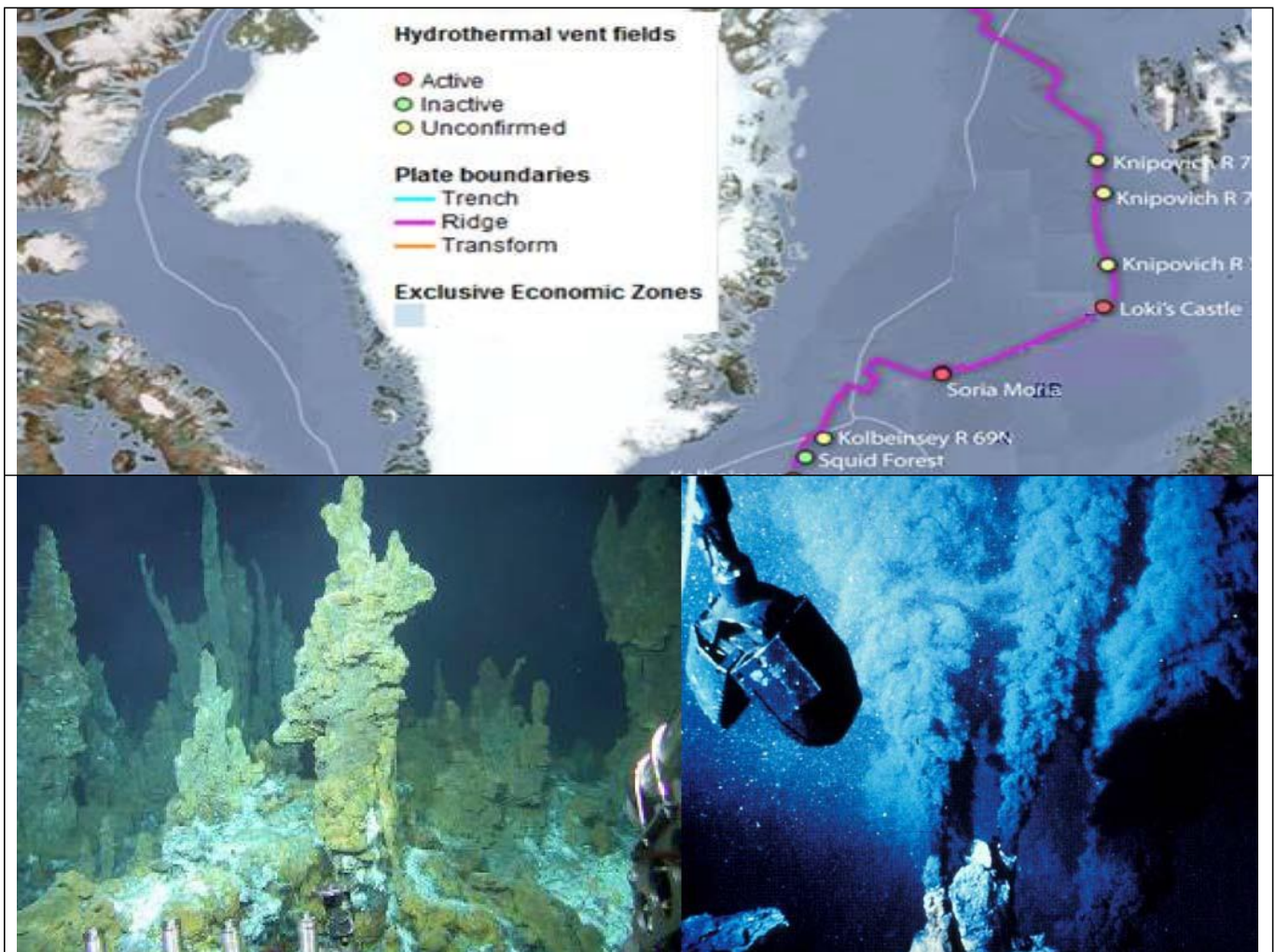


Seabed massive sulphide (SMS) resource assessment within the Norwegian Economic Exclusive Zone (NEEZ).



Prepared and submitted jointly by Richard Sinding-Larsen and Steinar Ellefmo

Seabed massive sulphide resource assessment of undiscovered potentially recoverable Copper, Zinc, Silver, and Gold related to hydrothermal vent fields on the Mid-Atlantic ridge within the Norwegian Economic Exclusive Zone



Seabed massive sulphide resource assessment of undiscovered potentially recoverable Copper, Zinc, Silver, and Gold related to hydrothermal vent fields on the Mid-Atlantic ridge within the Norwegian Economic Exclusive Zone

By

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Abstract

Information on the general locations and amounts of undiscovered seabed massive sulphide resources within the Norwegian Economic Exclusive Zone will be increasingly important to exploration and resource managers, environmental planners, economists, and policymakers as we hopefully progress towards tapping these resources. This report contains the results of probabilistic estimates of the amounts of metal of copper (Cu), zinc (Zn), silver (Ag), and gold (Au) in known and undiscovered seabed massive sulphide vent fields on the Mid-Atlantic ridge within the Norwegian Economic Exclusive Zone. The play analysis methodology that was used to make these estimates allows for an explicit expression of the estimates of undiscovered resources and their associated uncertainty in a form that is useful to decision makers. A combination of the probability distributions of the estimated number of undiscovered vent fields, the grades, and the tonnages was used to obtain the probability distributions for undiscovered metals. A preliminary “gross in situ” economic valuation concludes this report.

There are 3 surveyed and a number of inferred seabed massive sulphide vent fields on the Norwegian Mid-Atlantic ridge. To define favorable zones for vent fields, morphostructural and geodynamic analysis of bathymetric data was used according to the criteria established by the Gramberg All-Russian Institute of Geology and Mineral Resources of the World Ocean (VNIIO keangeologiya), St. Petersburg, Russia. In addition to the inferred vent fields concealed vent fields may exist with less bathymetric expression than the ones inferred.

The total inferred, and postulated undiscovered metal amounts to an expected endowment of 6.4 million metric tonnes of copper metal in addition to zinc (6.5 million metric tonnes), gold (170 metric tonnes), and silver (9901 metric tonnes). Due to the lack of detailed data along this frontier exploration area a large uncertainty is attached to these results with a huge upside potential. There is accordingly a 5% probability of having metal resources of more than or equal to 20 million metric tonnes of copper metal, 21 million metric tonnes of zinc, 652 metric tonnes of gold, and 32883 metric tonnes of silver.

The expected gross in situ value of the two ridges are 71 billion US\$ which is close to one-tenth of the Norwegian Oil fund (value per mid 2013) with an upside at the 5% level of 229 billion US\$ which is approximately one-third of the Norwegian Oil fund. These estimates are based upon postulated and inferred undiscovered resources and the calculated gross in situ value does not consider factors such as costs and, as a result, overstates the potential value of the SMS deposits. Further exploration in the years to come will hopefully confirm the existence of the assessed resources as well as the costs and viability of their development and thereby reduce the large uncertainty that at the present time is related to their tonnages and gross in situ value.

Table 1 Results of the aggregated assessment of the metal resource potential on the combined Mohn-and Knipovich Ridges.

| Resource type Yet-to-find | Dist, type | Mode | Mean | Std, dev, | F95 | F75 | F50 | F25 | F5 |
|---------------------------------|------------|--------|---------|-----------|--------|---------|---------|---------|----------|
| Cu metal [metric tonnes] | | | | | | | | | |
| Number of SMS accumulations | MC(9999) | | 155 | 112 | 32 | 75 | 125 | 205 | 382 |
| Accumulation size | MC(10000) | 919 | 45029 | 142463 | 0 | 1466 | 4058 | 20317 | 221634 |
| Cond, aggregate potential | MC(9979) | 10704 | 6365811 | 6867941 | 245513 | 1665430 | 4119505 | 8722759 | 20005536 |
| Uncond, aggregate potential | Result-r | | 6352443 | 6866911 | 236019 | 1651995 | 4105396 | 8708715 | 19992125 |
| Zn metal [metric tonnes] | | | | | | | | | |
| Number of SMS accumulations | MC(10000) | | 155 | 110 | 41517 | 76 | 126 | 205 | 377 |
| Accumulation size | MC(10000) | 529 | 46132 | 145198 | 0 | 1928 | 6414 | 19966 | 217152 |
| Cond, aggregate potential | MC(9974) | 107006 | 6506070 | 6984227 | 255420 | 1698236 | 4187731 | 8900295 | 20525222 |
| Uncond, aggregate potential | Result-r | | 6489154 | 6983006 | 239590 | 1679522 | 4170528 | 8882545 | 20508462 |
| Au metal [metric tonnes] | | | | | | | | | |
| Number of SMS accumulations | MC(9999) | | 155 | 111 | 32 | 74 | 127 | 205 | 378 |
| Accumulation size | MC(10000) | 0,012 | 0,98 | 41309 | 0 | 0 | 0 | 0 | 30011 |
| Cond, aggregate potential | MC(9974) | 0,022 | 170 | 250 | 31079 | 41480 | 82 | 203 | 652 |
| Uncond, aggregate potential | Result-r | | 170 | 250 | 23774 | 41389 | 81 | 203 | 651 |
| Ag metal [metric tonnes] | | | | | | | | | |
| Number of SMS accumulations | MC(9998) | | 153 | 109 | 33 | 74 | 124 | 202 | 377 |
| Accumulation size | MC(10000) | 2,250 | 64 | 213 | 0 | 31809 | 41284 | 41543 | 303 |
| Cond, aggregate potential | MC(9982) | 0,421 | 9901 | 11305 | 334 | 2302 | 5939 | 13502 | 32883 |
| Uncond, aggregate potential | Result-r | | 9883 | 11302 | 320 | 2285 | 5923 | 13480 | 32863 |

Table 2 Results of the aggregated assessment of the metal resource potential on the Mohn Ridge and its gross value calculated from rounded 2013 prices (including week 44).

| Resource type and magnitude | Dist, type | Mode | Mean | Std, dev, | F100 | F95 | F90 | F75 | F50 | F25 | F10 | F5 | F0 |
|--|-----------------|----------------|---------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|
| Cu metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9979) | 4138 | 2817909 | 3483775 | 1991 | 59023 | 149136 | 526256 | 1562407 | 3747100 | 7139214 | 9968584 | 18890808 |
| Zn metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9974) | 4821 | 2854343 | 3610548 | 2027 | 53066 | 145351 | 522911 | 1568694 | 3762098 | 7183589 | 10047893 | 19866846 |
| Au metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9974) | 0,04 | 75 | 132 | 0,02 | 0,61 | 1,67 | 6,78 | 25,70 | 79,60 | 205,40 | 329,70 | 815,40 |
| Ag metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9982) | 1,58 | 4346 | 5906 | 2 | 69 | 194 | 709 | 2207 | 5509 | 11212 | 16200 | 34570 |
| Resource type and gross value | | | | | | | | | | | | | |
| | \$/tonne | Mode | Mean | Std, dev, | F100 | F95 | F90 | F75 | F50 | F25 | F10 | F5 | F0 |
| Cu metal gross value [10⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 7000 | 0,0290 | 19,7254 | 24,3864 | 0,0139 | 0,4132 | 1,0440 | 3,6838 | 10,9369 | 26,2297 | 49,9745 | 69,7801 | 132,2357 |
| Zn metal gross value [10⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 2000 | 0,0096 | 5,7087 | 7,2211 | 0,0041 | 0,1061 | 0,2907 | 1,0458 | 3,1374 | 7,5242 | 14,3672 | 20,0958 | 39,7337 |
| Au metal gross value [10⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 41800643 | 0,0017 | 3,1225 | 5,5177 | 0,0008 | 0,0254 | 0,0698 | 0,2834 | 1,0743 | 3,3273 | 8,5859 | 13,7817 | 34,0842 |
| Ag metal gross value [10⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 643087 | 0,0010 | 2,7946 | 3,7982 | 0,0012 | 0,0442 | 0,1244 | 0,4557 | 1,4192 | 3,5426 | 7,2103 | 10,4181 | 22,2313 |
| Total gross metal value [10⁹ US\$] | | | | | | | | | | | | | |
| | | 0,04 | 31,35 | | 0,02 | 0,59 | 1,53 | 5,47 | 16,57 | 40,62 | 80,14 | 114,08 | 228,28 |
| % of Norways oil fund 738 10⁹ US\$ | | | | | | | | | | | | | |
| | | 0,006 % | 4,25 % | | 0,003 % | 0,080 % | 0,207 % | 0,741 % | 2,245 % | 5,505 % | 10,859 % | 15,457 % | 30,933 % |

Table 3. Results of the aggregated assessment of the metal resource potential on the Knipovich Ridges and its gross value calculated from rounded 2013 prices (including week 44).

| Resource type and magnitude | Dist, type | Mode | Mean | Std, dev, | F100 | F95 | F90 | F75 | F50 | F25 | F10 | F5 | F0 |
|--|-----------------|----------------|---------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|
| Cu metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9979) | 991,20 | 3586654 | 3685212 | 2232 | 114926 | 275451 | 878875 | 2402414 | 5073538 | 8782509 | 11167472 | 18737424 |
| Zn metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9974) | 298,30 | 3728166 | 3890234 | 2041 | 106862 | 285055 | 901097 | 2427474 | 5294048 | 9005806 | 11765989 | 20283549 |
| Au metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9974) | 0,01 | 97 | 141 | 0,0149 | 1,16 | 3 | 13 | 45 | 118 | 252 | 391 | 812 |
| Ag metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9982) | 3,68 | 5506 | 6041 | 5 | 154 | 367 | 1230 | 3420 | 7657 | 13597 | 17984 | 31669 |
| Resource type and gross value | \$/tonne | Mode | Mean | Std, dev, | F100 | F95 | F90 | F75 | F50 | F25 | F10 | F5 | F0 |
| Cu metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 7000 | 0,0069 | 25,1066 | 25,7965 | 0,0156 | 0,8045 | 1,9282 | 6,1521 | 16,8169 | 35,5148 | 61,4776 | 78,1723 | 131,1620 |
| Zn metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 2000 | 0,0006 | 7,4563 | 7,7805 | 0,0041 | 0,2137 | 0,5701 | 1,8022 | 4,8549 | 10,5881 | 18,0116 | 23,5320 | 40,5671 |
| Au metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 41800643 | 0,0002 | 4,0505 | 5,8772 | 0,0006 | 0,0485 | 0,1354 | 0,5518 | 1,8936 | 4,9158 | 10,5421 | 16,3441 | 33,9296 |
| Ag metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 643087 | 0,0024 | 3,5407 | 3,8850 | 0,0029 | 0,0992 | 0,2357 | 0,7912 | 2,1994 | 4,9240 | 8,7439 | 11,5653 | 20,3657 |
| Total gross metal value [10⁹ US\$] | | 0,01 | 40,15 | | 0,02 | 1,17 | 2,87 | 9,30 | 25,76 | 55,94 | 98,78 | 129,61 | 226,02 |
| % of Norways oil fund 738 10⁹ US\$ | | 0,001 % | 5,44 % | | 0,003 % | 0,158 % | 0,389 % | 1,260 % | 3,491 % | 7,580 % | 13,384 % | 17,563 % | 30,627 % |

Table 4. Results of the aggregated assessment of the metal resource potential on the Mohn-and Knipovich Ridges and its gross value calculated from rounded 2013 prices (including week 44).

| Resource type and magnitude | Dist, type | Mode | Mean | Std, dev, | F100 | F95 | F90 | F75 | F50 | F25 | F10 | F5 | F0 |
|--|-----------------|----------------|---------------|------------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|-----------------|
| Cu metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9979) | 10704 | 6365811 | 6867941 | 8900 | 245513 | 550849 | 1665430 | 4119505 | 8722759 | 15076829 | 20005536 | 36874515 |
| Zn metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9974) | 107006 | 6506070 | 6984227 | 8910 | 255420 | 577318 | 1698236 | 4187731 | 8900295 | 15526693 | 20525222 | 37999290 |
| Au metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9974) | 0,022 | 170 | 250 | 0,0623 | 3 | 7 | 26 | 82 | 203 | 430 | 652 | 1529 |
| Ag metal Yet-to-find [metric tonnes] | | | | | | | | | | | | | |
| Cond, aggregate potential | MC(9982) | 0,421 | 9901 | 11305 | 10 | 334 | 755 | 2302 | 5939 | 13502 | 24293 | 32883 | 61799 |
| Resource type and gross value | \$/tonne | Mode | Mean | Std, dev, | F100 | F95 | F90 | F75 | F50 | F25 | F10 | F5 | F0 |
| Cu metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 7000 | 0,0749 | 44,56 | 48,08 | 0,0623 | 1,72 | 3,86 | 11,66 | 28,84 | 61,06 | 105,54 | 140,04 | 258,12 |
| Zn metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 2000 | 0,2140 | 13,01 | 13,97 | 0,0178 | 0,51 | 1,15 | 3,40 | 8,38 | 17,80 | 31,05 | 41,05 | 76,00 |
| Au metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 41800643 | 0,0009 | 7,10 | 10,46 | 0,0026 | 0,12 | 0,31 | 1,07 | 3,42 | 8,49 | 17,97 | 27,24 | 63,92 |
| Ag metal gross value [10 ⁹ US\$] | | | | | | | | | | | | | |
| Cond, aggregate gross value | 643087 | 0,0003 | 6,37 | 7,27 | 0,0064 | 0,21 | 0,49 | 1,48 | 3,82 | 8,68 | 15,62 | 21,15 | 39,74 |
| Total gross metal value [10⁹ US\$] | | 0,29 | 71,04 | | 0,09 | 2,56 | 5,80 | 17,61 | 44,45 | 96,04 | 170,18 | 229,47 | 437,78 |
| % of Norways oil fund 738 10⁹ US\$ | | 0,039 % | 9,63 % | | 0,012 % | 0,347 % | 0,786 % | 2,386 % | 6,023 % | 13,013 % | 23,060 % | 31,094 % | 59,320 % |