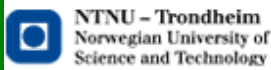
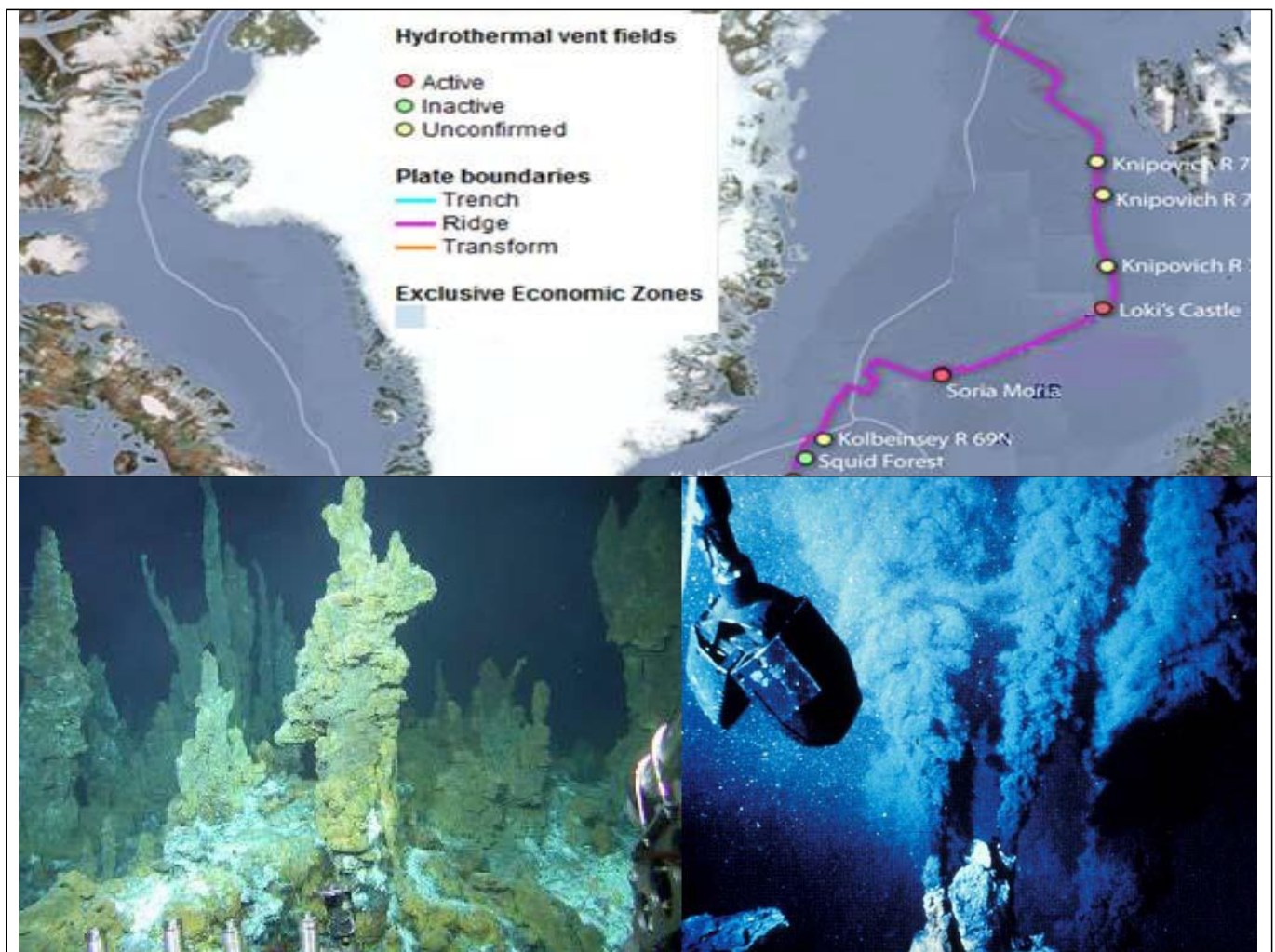


Seabed massive sulphide (SMS) resource assessment within the Norwegian Economic Exclusive Zone (NEEZ).



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 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 %