SOUTH NORWAY

TJOSÅS, TØRVIKNUTEN & SAUDA

Waterfilled strike drive at Tjosås.

Peter Wulff, Norrbotten Exploration AB, October 27th, 2011

CONTENT

Appendices: table 2 (NEAB's samples), table 3 (NGU's samples) and a CD containing this report.

1.1 INTRODUCTION & CONCLUSION

This report deals with three South Norwegian occurrences (fig. 1.1.1) which NEAB in year 2011 investigated again (Tjosås and Tørviknuten) or for the first time (Sauda).

TJOSÅS

Previous sampling had indicated that gold and copper correlate positively. This assumption was confirmed by two relatively copper-rich samples with 6.4 and 36.9 ppm gold. For being from a Norwegian VHMS, a sample with 37 ppm gold is quite unique and only surpassed by two samples from another of NEAB's occurrences, Storhidleren. Apart from gold, Tjosås also has significant grades of zinc and is county Sunnhordland's richest in this respect. Modern exploration has never been carried out at Tjosås. The Swedish company Geovista estimates that a ground-geophysical survey covering the stratigraphy hosting the Tjosås occurrence and a test pit 900 m to the west will cost about 150 KSEK. Such a survey is recommended.

TØRVIKNUTEN

A relatively extensive VHMS-related rustzone at Tørviknuten was mapped by NEAB in year 2009. The rustzone locally grades into massive pyrite with a few per cents of copper or zinc. In year 2009 other rustzones were noticed but not mapped. This was done in year 2011 but the two days spent did not result in samples with significant grades of base-metals or gold. Further work is thus not recommended.

SAUDA

The VHMS-style zinc occurrences and deposits at Sauda in county Rogaland are South Norway's most zinc-rich and a day was spent on the central and largest part, the Sauda deposit. 12000 tons grading 32.5% zinc and 1% copper have been produced at Sauda but further work is not recommended as tonnage potential appears absent and as the area has been investigated several times since WW2.

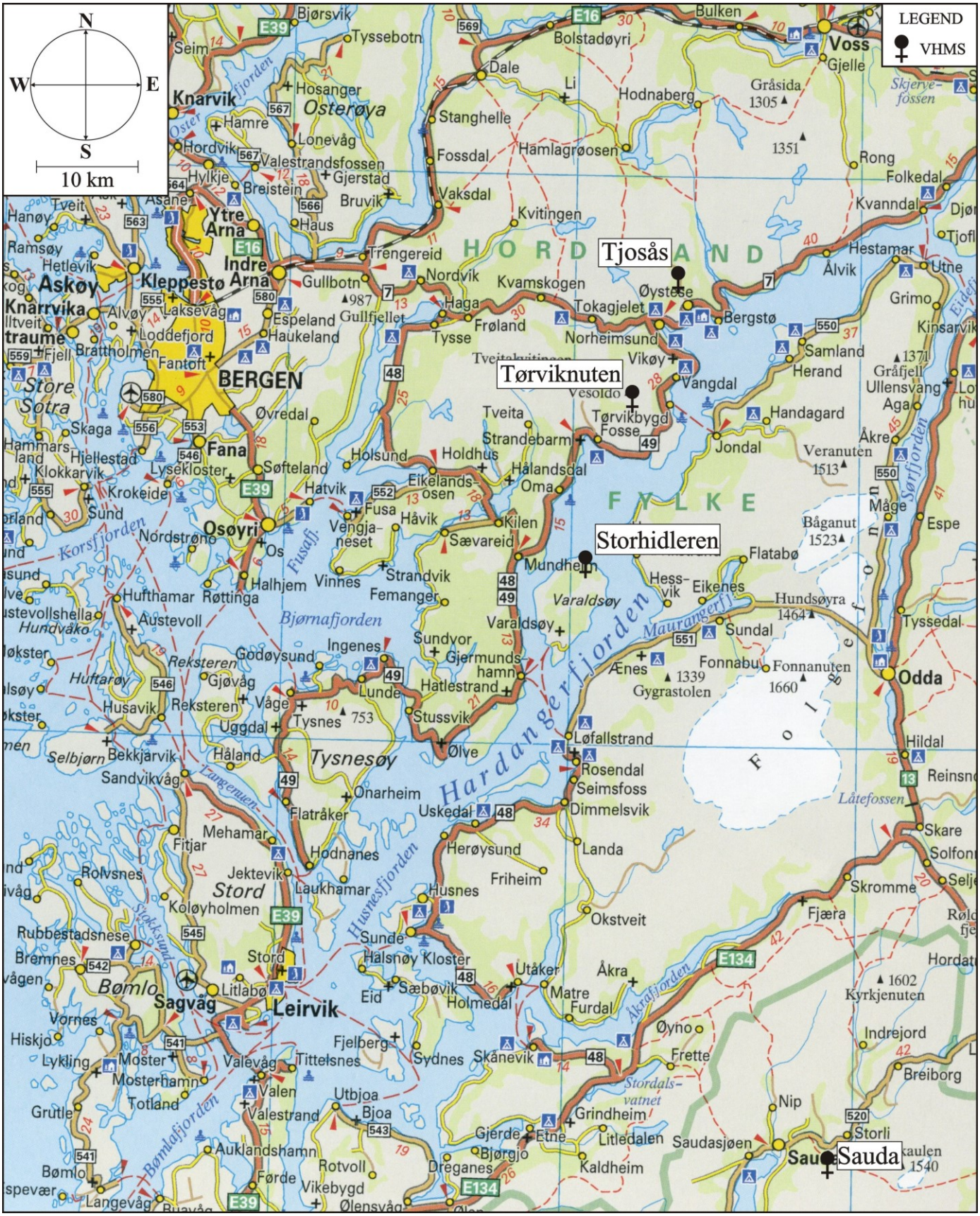

Fig. 1.1.1: Topographic map showing Tjosås, Tørviknuten and Sauda.

2.1 TJOSÅS

Location

The main occurrence is at UTM E343077, N6699537. From paved road it's thirty minutes of walking on a tractor road and then 200 m on a foot path. The occurrence is crossed by the Blåkollelvi – a creek only, despite its name. Tjosås may be snow covered well into May.

History

In Norges Bergverksdrift (1883) it is written that "last year, on land belonging to the farms Tjosaas and Stues, some occurrences with cupriferous pyrite and galena in quartz were test mined by Robert Milburn. After considerable effort, the unprofitable test mining had to be abandoned". In an undated report (Hagen), Tjosås is said to be too poor to warrant further investigation – this was at a time when sphalerite was considered waste. NGU (Korneliussen) passed the occurrence in 1977 and took two samples returning 0.28% & 1.2% Cu, 0.37% & 0.52% Pb and 5.7% & 1.4% Zn, respectively. Gold analysis was not routinely carried out at that time but NGU concluded that Tjosås was of some interest because of its relatively high Zn-content.

Geology

The Tjosås occurrence is hosted in bimodal Caledonian supracrustals similar to the Ølve-Varaldsøy group (fig. 2.1.1) and can be followed for about 75 m along strike. Figure 2.1.3 shows the old workings – it appears the eastern test pit and adit are too far south to hit the massive part of the mineralization but there is the same alteration as in the other old workings. Alternatively, the adit is instead a strike drive, i.e. the mineralization is folded in that area.

The mineralization is best seen at Tjo 2 and Tjo 5. At Tjo 2 there are two 10-15 cm thick layers of massive and fine-grained sulfide. At Tjo 5 only a 5 cm thick layer is observed but judging from 30 cm thick (across banding) specimens in the dump, there is or was more. The pyritic and pyrrhotitic sulfide layers have more sphalerite than any other VHMS mineralization in Sunnhordland. The sphalerite is light-colored and thus not particularly iron-rich. Chalcopyrite is also common but there is much less of it than of sphalerite. The alteration is typical – sericitization, chloritization, silicification and pyritization. In addition there is carbonatization which is uncommon in the district's other VHMS-occurrences. Host rock is phyllite, probably originally a mafic rock.

Samples

Nine ore samples (563032-563038 & 563128-29) and two chip-samples of footwall and hanging wall (563128-9) have been taken (table 2). Including NGU's two relatively poor samples (with regard to zinc), the ore samples average 6.6 ppm Au, 29 ppm Ag, 9.0 % Zn, 0.9% Cu and 0.5% Pb. Judging from the nine ore samples, it appears that there is more copper and gold in the westernmost of the old workings. The sample with 36.9 ppm gold is characterized by having three times more calcium and magnesium (i.e. carbonate) and much less sulphide than the other ore samples. It also has 50% more manganese. The reason for taking this particular sample was that it had relatively plenty and easily visible chalcopyrite. Unfortunately a hand specimen was not gathered. Both NGU's samples are high in manganese and then most likely also in carbonate. As one of them also has 1.4% copper it can be expected to be quite gold-rich. The two samples of the foot- and hanging-walls have nothing of interest.

Western test pit (Tjo 6)

At UTM E342196, N6699421, c. 900 meters WSW (figs. 2.1.2 & 2.1.4) of the actual Tjosås occurrence, is a $2m^3$ test pit. The test pit is on the same stratigraphic level as the other old workings. There is 40-50 cm of almost massive pyrite hosted in sericite schist resembling the one in the other old workings. Strike/dip is 57º/60ºW. Rustzones can be followed westwards for at least 1 km but actual mineralization was not observed. Three ore samples (563115-16 & 563130) have been taken from the western test pit. They have the same elements as the samples from the main occurrence but contents are much lower.

Further work

The high gold and zinc contents at Tjosås are uncommon among Norwegian VHMS occurrences (table 1) and the stratigraphic level hosting Tjosås is of considerable extent – tens of kilometers (figs. 2.1.1 & 2.1.2). Furthermore, the occurrence and the area in general have never seen any modern exploration. A ground-geophysical survey covering Tjosås and the western test pit is proposed (fig. 2.1.2). Swedish company Geovista estimates the cost at approximately 150 KSEK.

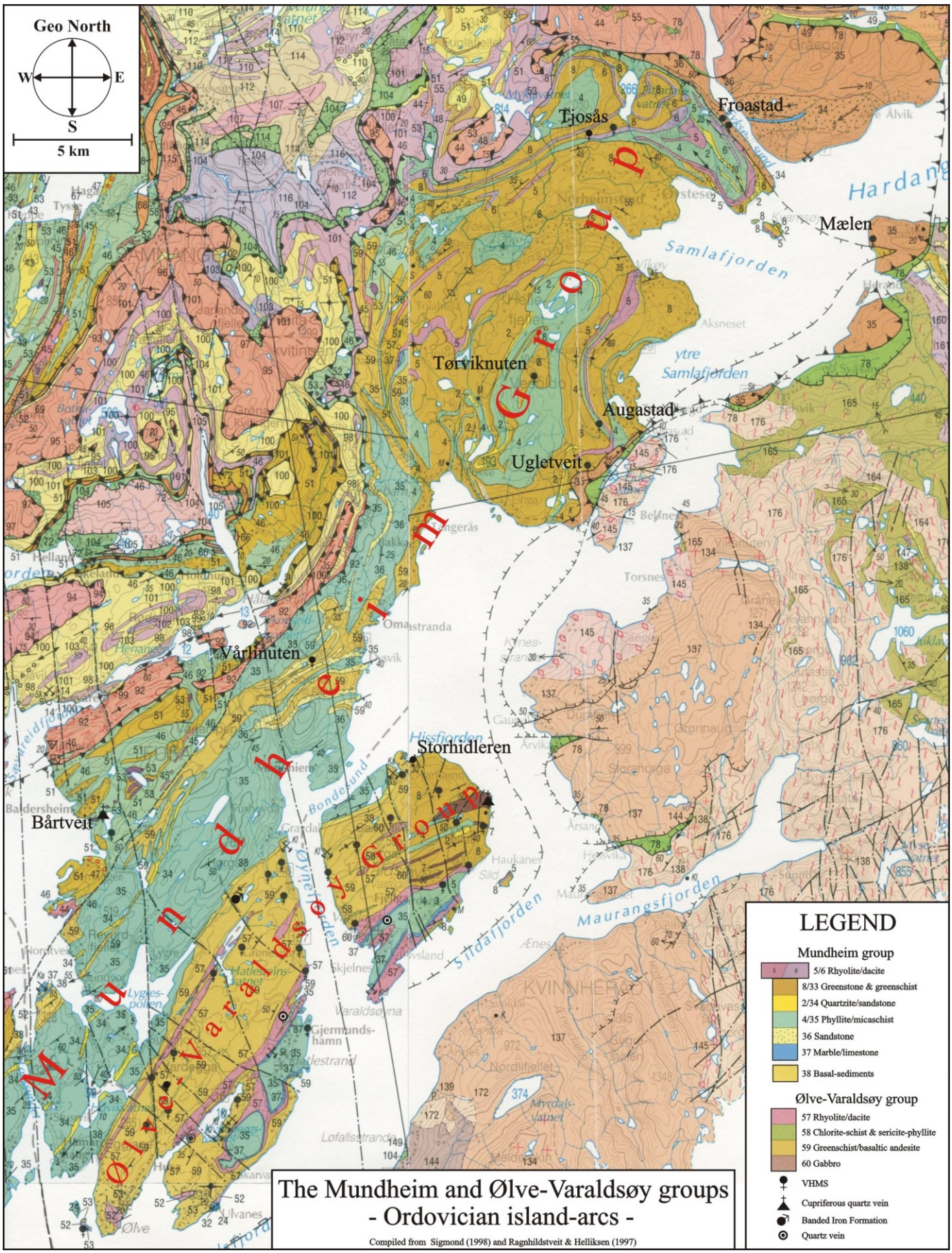

Fig. 2.1.1: Geological map of part of the Hardanger Fiord. According to NGU (pers. com.) the Mundheim and Ølve-Varaldsøy Groups may be one and the same albeit the latter is far more mineralized.

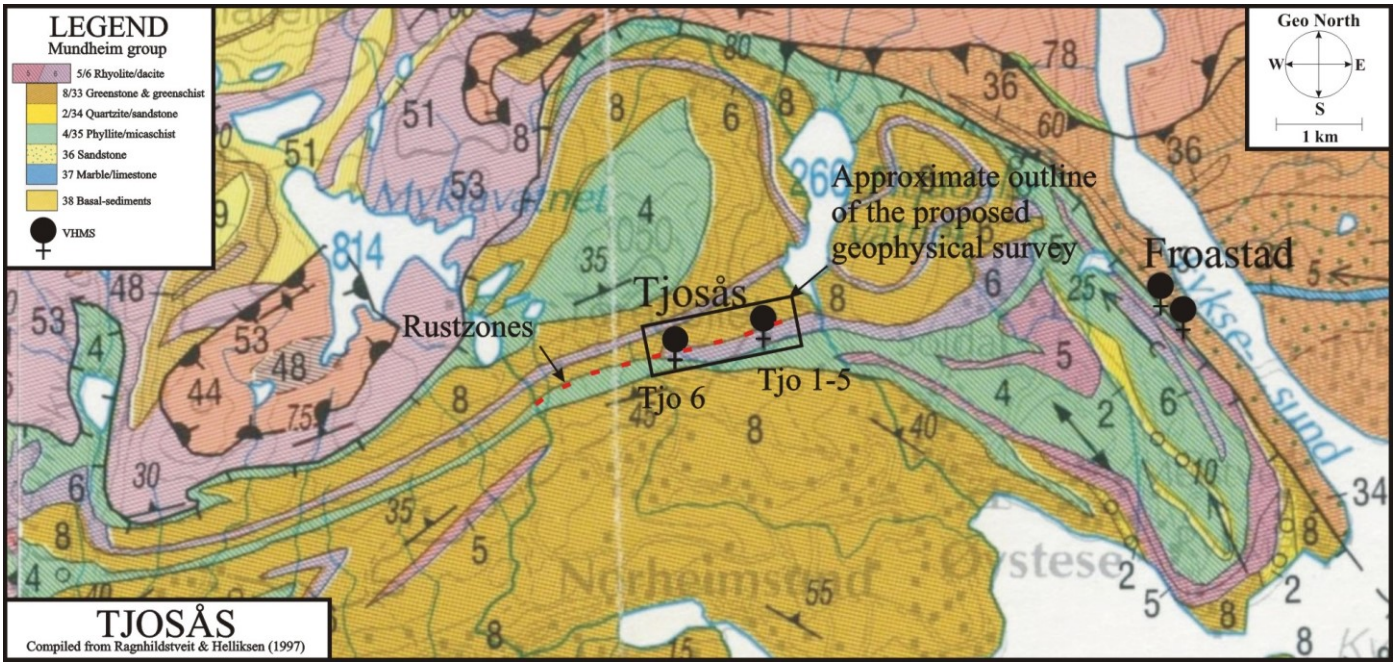

Fig. 2.1.2: Close-up of fig. 2.1.1. A belt of rustzones were followed for more than 1 km westwards from Tjo 6.

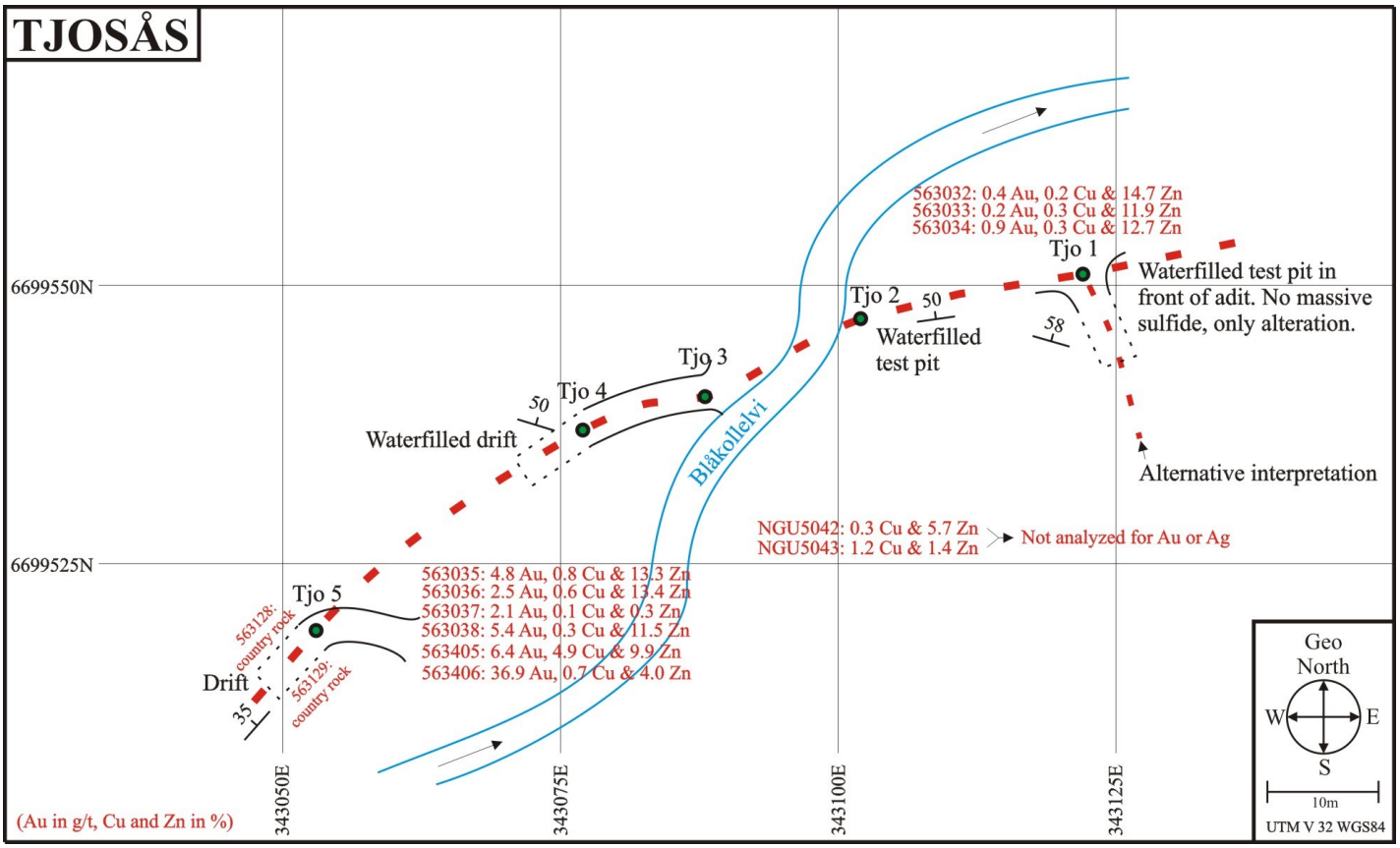

Fig. 2.1.3: Map showing the Tjosås occurrence and the NEAB-samples´ locations. The NGU-samples´ precise locations are unknown.

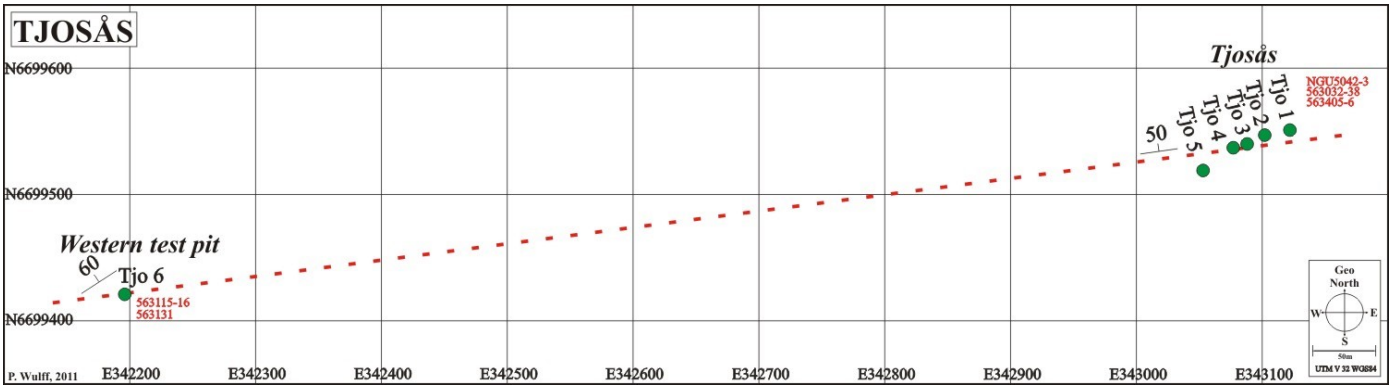

Fig. 2.1.4: map showing the six old workings at Tjosås.

Occurrence	# of samples	Au ppm	Max Au ppm	Ag ppm	Cu %	Zn %	Pb ppm	Cu+Zn+Pb %	As ppm	Sb ppm	Bi ppm	Fe %	Mo ppm
Storhidleren core	1	33.9	33.9	23	0.03	0.02	145	0.06	307	<5	6	28	239
Storhidleren 30 kilo	1	23.9	23.9	41	0.02	0.02	295	0.07	1300	135	3	21	190
Storhidleren chip	22	14.0	130.0	17	0.01	0.04	230	0.07	326	24	2	16	157
Storhidleren grab	21	12.2	45.3	31	0.02	0.02	279	0.07	1250	37	u.d.	23	99
Vardtjønnbekken	2	10.3	11.0	27	0.89	5.27	1858	6.35	93	3	6	35	10
Tjosås	9	6.6	36.9	29	0.89	8.98	5312	10.40	134	10	8	20	16
Godejord	11	4.8	15.9	106	2.66	8.49	2821	11.44	30	5	10	13	20
Flatskarvåsen	3	2.7	4.8	5	3.08	0.02	3	3.10	185	18	29	22	10
Haukanes	7	2.5	9.7	35	1.14	4.25	1728	5.6	402	9	3	31	80
Skyttemyr	8	2.4	7.2	33	3.45	3.60	84	7.1	274	4	63	15	5
Raudvatnet	5	2.4	7.3	122	0.62	5.14	4724	6.2	86	12	7	7	38
Uraberget	2	2.0	2.4	54	1.51	3.33	839	4.9	1145	11	14	37	117
Svinland	3	1.5	4.3	28	0.58	3.68	3911	4.7	1567	16	4	26	30
Brennfjellmyra	5	1.4	3.3	2	1.19	0.03	13	1.2	40	0	33	5	2
Tilset	4	1.3	4.7	23	2.12	0.06	10	2.2	3	0	19	19	0
Femsteinevik	2	1.3	1.8	52	1.50	2.94	2105	4.7	175	u.d.	48	31	50
Kvitsand	8	1.2	2.9	15	2.31	0.28	644	2.7	215	7	73	21	63
Hestkletten	3	1.2	3.1	62	4.74	5.69	13554	11.8	10367	56	157	21	19
Tjørnvollmyran	5	1.2	3.3	27	4.89	1.52	3776	6.8	10	0	67	19	25
Tømmeråsfjellet	2	1.1	1.7	1	0.01	0.04	15	0.1	591	0	0	17	1
Børskneppen	8	1.1	3.6	8	3.33	0.12	54	3.4	1	1	16	13	2
Øytrø	10	1.1	2.1	49	0.69	6.83	1721	7.7	2009	7	4	12	2
Gråskolt	4	1.0	1.4	47	1.82	2.63	1710	4.6	475	5	u.d.	33	38
Løvlibekk	6	0.9	2.0	14	1.99	0.16	16	2.1	7	3	18	13	4
Ramfjell	3	0.9	1.9	4	1.57	0.31	3	1.9	9	5	5	13	5
Våraviken	5	0.8	1.8	62	1.59	8.60	19728	12.2	236	92	250	28	16
Mannfjell	14	0.7	3.7	29	0.97	3.95	385	5.0	69	2	5	14	2
Rosset	13	0.7	5.3	17	1.06	2.37	396	3.5	63	2	11	16	4
Forneset	3	0.6	1.9	49	0.96	0.01	11	1.0	4	1	7	9	428
Fines	17	0.6	6.9	38	2.62	0.63	5123	3.8	11	3	40	13	72
Søndre Geitryggen	12	0.6	3.1	20	1.06	1.18	501	2.3	52	0	11	18	16
Nygruven	5	0.6	1.3	19	0.87	3.15	2987	4.3	58	2	10	22	2
Storenga	2	0.6	1.1	11	0.96	1.18	1660	2.3	386	15	20	19	0
Gullberg	3	0.6	1.2	24	4.10	0.22	157	4.3	98	0	15	28	10
Rundhaugen	5	0.5	1.3	12	3.20	0.93	724	4.2	95	10	59	28	2
Varglibusta	3	0.5	1.5	4	1.57	0.03	11	1.6	0	1	5	13	1
Mælen	5	0.5	1.2	26	0.80	1.77	2803	2.9	466	5	12	36	6
Visletten	10	0.5	2.1	26	0.45	2.87	1884	3.5	46	3	11	17	1
Nya Solskinn	6	0.5	1.0	10	4.92	1.67	337	6.6	1	19	70	30	4
Average	**7**	**3.6**	**10.2**	**31**	**1.70**	**2.36**	**2117**	**4.3**	**579**	**14**	**30**	**21**	**46**

Table 1: Average contents of samples from Norwegian VHMS occurrences with at least one sample >1 ppm gold and average gold content >0.5 ppm gold. The occurrences marked with green were sampled by NEAB and are located in county Sunnhordland. The other occurrences were sampled by NGU and the data comes from a database with 2744 samples from 2-300 VHMS occurrences. NGU's samples are from outcrops and dumps, as are NEAB's. Data on sulphur content are incomplete and were omitted but contents of Fe+base metals indicate the contents of sulphur. Both Storhidleren and Tjosås stand out because of their high average and maximum values gold values. Storhidleren is noticeable by being practically devoid of base metal while Tjosås has the highest zinc content. On the whole, NEAB's VHMS occurrences are overrepresented among auriferous Norwegian VHMS occurrences.

Fig. 2.1.5: Banded and deformed massive pyrite and sphalerite. The sphalerite mostly occurs in a 1 cm thick band in the middle part of the sample. The minor chalcopyrite mostly occurs in/adjacent to quartz and chlorite. Not analyzed.

Fig. 2.1.6: Massive and deformed chalcopyrite, pyrite and sphalerite in quartz matrix. Traces of a grey mineral may be galena and/or sulphosalts. This sample (563405) has relatively high grade of chalcopyrite and is with respect to copper the richest (4.9% Cu) analyzed. Gold content is 6.4 ppm - second highest of the Tjosås samples.

Fig. 2.1.7: Sample 563038. Massive pyrite and sphalerite with minor chalcopyrite. Silicates are quartz, carbonate and chlorite. 5.44 ppm gold and 12% zinc, copper and lead.

Fig. 2.1.8: Massive and deformed sphalerite and pyrite with traces of chalcopyrite and possibly galena. Silicates are quartz and minor chlorite. Not analyzed but of high grade with regards to zinc – probably in excess of 20%.

2.2 TØRVIKNUTEN

Location

Tørviknuten is remote and from paved road it takes 2-3 hours to reach the top of the 1028 m high mountain. There may be partial snow cover well into June.

History

Unnamed (1911) writes: ”the 900 m high mountain Tørviknuten between Strandebarm and Tørvikbygden in Hardanger, hosts a pyrite occurrence which starts at c. 800 m and goes right up to the top of the mountain. Strike is NW and dip is 30º SW. The thickness and grade of the occurrence varies and ranges from ½ to 2 meters. The pyrite impregnation is uneven and mostly of low grade. The impregnation occurs as stripes which sometime have 30-35% sulphur. Massive pyrite does not occur. The occurrence is of considerable strike length, there’s impregnation along 450 m, half of which is at least 1 m thick and grades 15-20% sulphur”. The report concludes that the ore area is about 200 m^2 @ 15-20% sulphur but its location is unfortunate and thus cannot be recommended.

Geology

The mineralizations/rustzones are hosted in bimodal Caledonian supracrustals similar to the Ølve-Varaldsøy group (fig. 2.1.1). The largest of the rustzones (fig. 2.2.1) can be followed more or less continuously along strike for about 1.5 km – thus being one of Sunnhordland’s larger ones. It stands out as an easily trackable rustzone in an area almost devoid of vegetation. Blast holes were noticed twice. When entering the eastern side of Store Goddalen, the largest rustzone disappears for about 280 m but is instead represented by sporadic outcrops of a vividly green quartz-vein (or layer?) hosted by equally green chlorite enriched in chromium. The rustzones are generally made up of disseminated pyrite in a chloritic, sericitic and quartzy matrix. Massive pyrite occurs locally in the rustzones and reaches a thickness of 60 cm at UTM E340014, N6689212, which is also one of the few places where chalcopyrite was noticed. The northernmost rustzones are hosted by chlorite schist (basalt) while the smaller ones to the southwest are hosted by rhyolite. There is no susceptibility contrast between the rustzones and their country rocks.

Samples

Sixteen samples: 563162-70 & 563409-15 (table 2). One sample has 3% Zn while another has 1.3% Cu. Highest gold value is 0.91 ppm. The sixteen samples average 0.2 ppm Au, 0.33% Cu and 0.29% Zn. The samples of massive pyrite closely resemble those from the westernmost test pit (Tjo6) at Tjosås, both visually and with regard to contents of base- and precious metals.

Further work

More rustzones/mineralizations were found and mapped in 2011 but grades continue to be low. Further work is thus not called for.

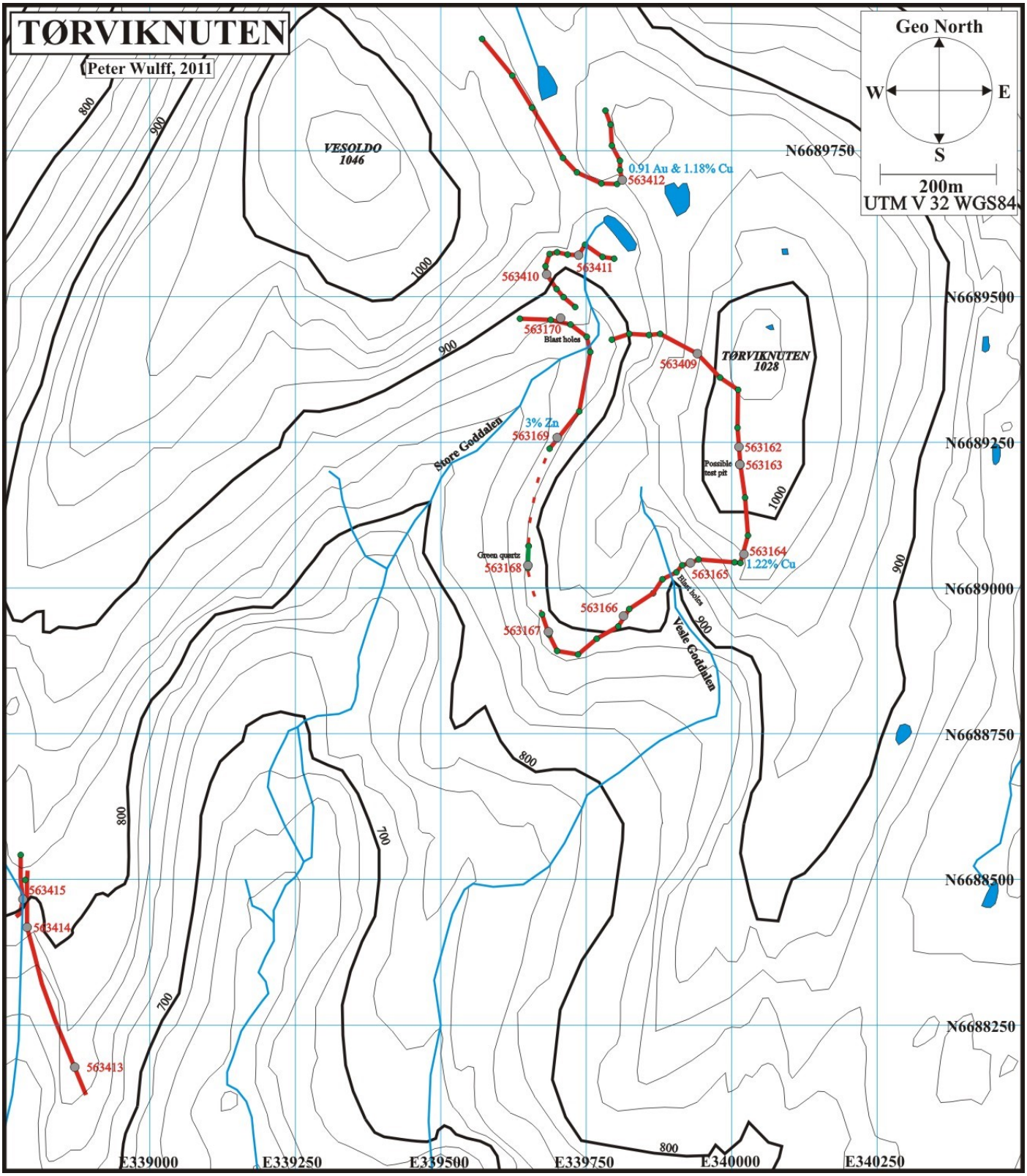

Fig. 2.2.1: Map showing the VHMS-related rustzones in the Tørviknuten and Vesoldo area. The ones in the south-western corner are developed in rhyolite while the others are in basalt.

Fig. 2.2.2: Disseminated pyrite and traces of sphalerite in folded, greenish quartz (with fuchsite?) and sericite. Sample 563414.

Fig. 2.2.3: Semi-massive pyrite and traces of chalcopyrite in quartz and sericite. Sample 563412 is the most gold rich (0.91 ppm) and second most copper rich (1.18% Cu) specimen at Tørviknuten although this is not evident in this particular cut. The chalcopyrite occurs in pressure shadows of the harder pyrite.

2.3 SAUDA

Location

The main entrance to the Sauda mine is just south of Storelva, at UTM E357990, N6615210.

History

The deposit was discovered in 1881 and was mined continuously from 1882 to 1898 after which it was test mined from time to time until 1919. Over the years about 24000 m^3 were mined from which 12000 tons of ore grading 31.5% zinc were handsorted and exported. British Petroleum mapped the area in detail in 1984-85 (a time when oil companies had to commit to mineral exploration in return for getting Norwegian oil licenses) and in year 2000 NGU sampled and described the Sauda deposit and nearby occurrences. There are numerous reports in NGU's archive in Trondheim.

Geology

Including Storli and Lægdene, the whole mineralized zone (fig. 2.3.1) extends for about 3.8 km – if it is continuous, that is. The part I walked along, from the main entrance of the Sauda mine to the Holmen test pits (2.3.2) appears to be continuous, i.e. the mineralized zone is marked by old workings, a rustzone or a topographical low. The latter is especially prominent between Dahls Gruve and Holmen. Besides Storgangen (the main ore) there are two other mineralized horizons at the Sauda mine. One of them, the Gilbertgangen, seems to have been mined too. The Breidkvam occurrence is in another stratigraphical horizon but judging from NGU's samples (table 3) the ore is similar to the other mineralizations. Maximum ore thickness in the Sauda mine (fig. 2.3.3) is said to have been three meters. In outcrop I saw nothing exceeding half a meter of massive sulphide. The deposit is tectonized and its metamorphic grade is amphibolite facies so primary features have more or less been lost. Silicification is still obvious, however. Country rocks are probably both felsic supracrustals and basalt.

Samples

In year 2000 NGU took 38 samples (table 3) from Sauda and the other, nearby occurrences so there was no need for NEAB to analyze more. Instead 4 different types of ore were cut and polished. Figures 2.3.4 and 2.3.5 show the richest type which occurs in all the dumps looked at and probably runs about 35-40% zinc. Figures 2.3.6 and 2.3.7 show other ore facies which would not have been considered ore at the time of mining.

NGU did not analyze the total zinc content of the 38 samples but 14 samples run more than 10% zinc. Estimates of the true zinc contents of these 14 samples have been calculated on the basis of the average zinc/cadmium ratio of samples with 1-9.9% zinc (excluding upper and lower ratio extremes). Maximum zinc value is then 33% in sample RO0077.01 (table 3), i.e. on a par with the reported 32.5% of the exported ore. Highest gold value is only 0.9 ppm – in this particular sample coupled to relatively high copper content (3.6%).

Further work

Grades of zinc are high in Sauda and the other, nearby occurrences and at 3.8 km the whole system's strike length is considerable. However, relative to the similarly considerable mining efforts, the production of only 12000 tons of ore is disappointing. Besides, the area has recently been explored. Further work is thus not recommended.

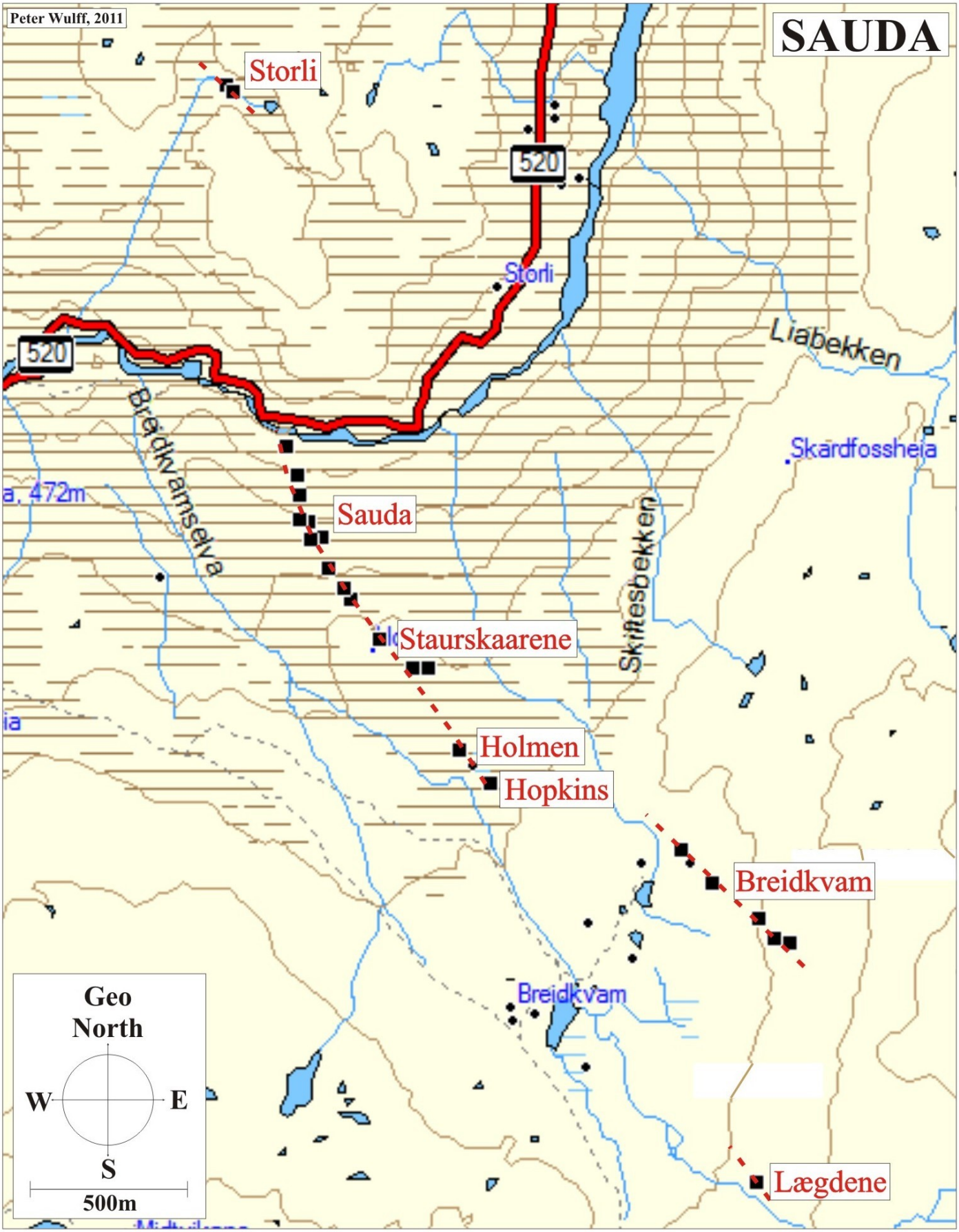

Fig. 2.3.1: Map showing the Sauda VHMS deposit and nearby occurrences.

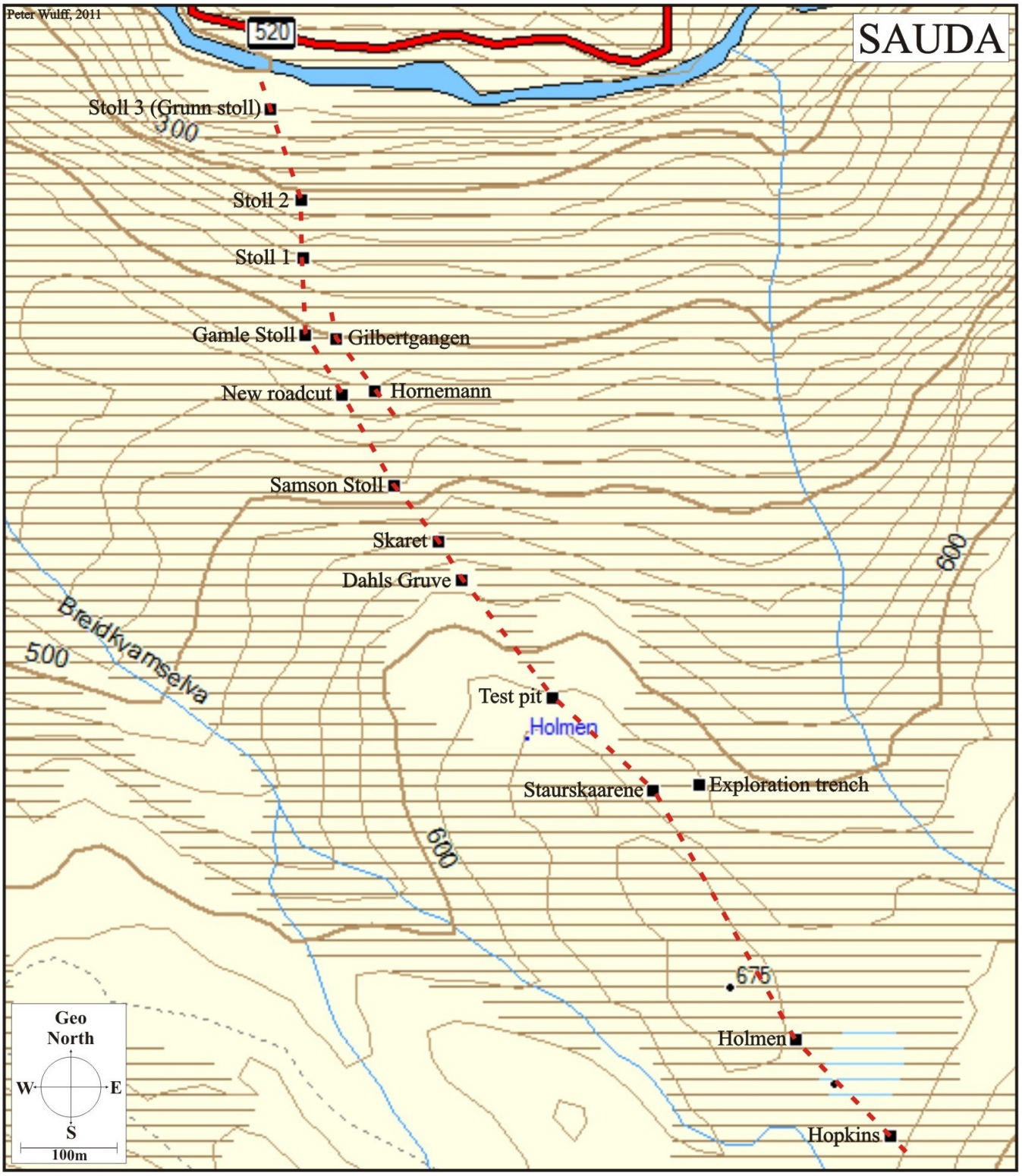

Fig. 2.3.2: Close up of the central part of the Sauda area.

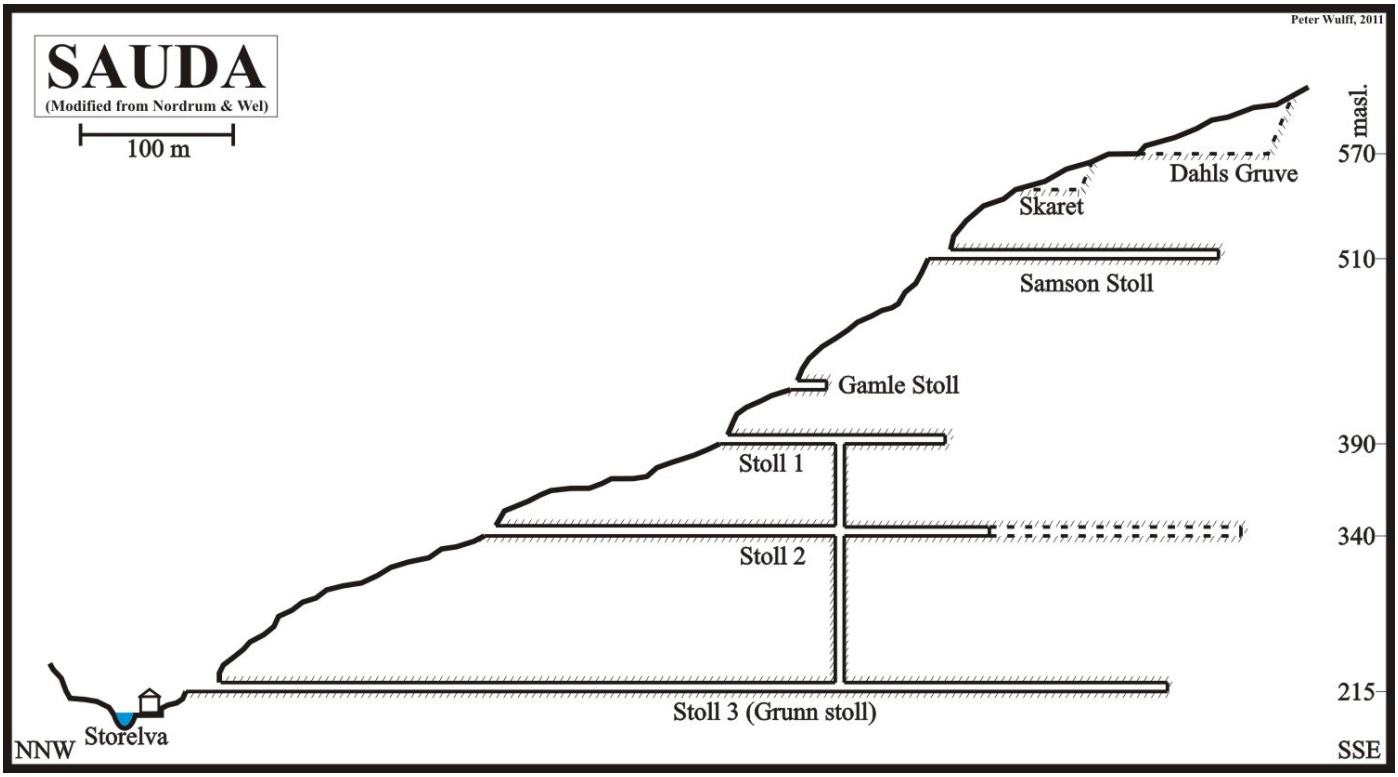

Fig. 2.3.3: Section of the mining area from where 12000 tons grading 32.5% zinc and 1% copper were extracted.

Fig. 2.3.4: Massive sphalerite with some pyrite and quartz. From Holmen. Not analyzed but >20% zinc. The sphalerite is dark and thus iron-rich.

Fig. 2.3.5: Massive sphalerite with 10% pyrite and a few grains of arsenopyrite. Silicates are quartz and amphibole. From Dahls gruve. Not analyzed.

Fig. 2.3.6: Semi-massive tectonized pyrite, pyrrhotite and chalcopyrite with minor sphalerite. From "New Roadcut". Silicates are amphibole and quartz. Not analyzed.

Fig. 2.3.7: Semi-massive pyrrhotite, chalcopyrite and sphalerite. Matrix is amphibole. From Gilbertgangen. Not analyzed.