Martin Frobisher's largest 'gold mine' in Baffin Island

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Abstract

Countess of Sussex Mine, south-east Baffin Island, was worked for two weeks in August 1578, during which time it produced 455 tons of rock, which were loaded on to seven small ships and sent to England. It was Frobisher's largest mine and reputedly rich in gold and silver. The ore was mainly metamorphosed ultramafite *(black ore)* and subsidiary metamorphosed (garnetiferous) mafite *(red ore)*. It extended, intermittently, 1400 metres across two peninsulas. A representative half-ton assay, made in England in 1579, gave disappointing but far from negligible returns. However, even these results (rate of 1.2 ozAu/T) were flawed by incorrect techniques and mistakes in calculation. According to recent analyses, the gold result was about 10,000 times too high.

This assay dashed the last hopes of the mining adventurers. The metallurgical plant at Dartford, Kent, soon closed, the Countess of Sussex deposit was forgotten, and the mining escapade came abruptly to an end.

Introduction

Martin Frobisher, the Elizabethan mariner who sought the North-west Passage (1576) and defended England against the Spanish Armada (1588), is less well known as the leader of two mining expeditions (1577, 1578) which must be regarded as the first serious attempts to win metals from the Americas north of Mexico. They were also the first of many expeditions that resulted in British sovereignty of the Canadian Arctic islands and which eventually led to the incorporation of this vast territory into the Dominion of Canada.

The mines themselves (Fig 1) were financial disasters. During the short life of the mining venture (1577-81), the mood of investors plummeted from exuberance in mid 1577 to utter despair in early 1579. The fortunes of the Countess of Sussex Mine, initially the white hope of the Cathay Company, epitomize this transition.

The Countess of Sussex deposit, which became Frobisher's largest gold mine, and reputedly one of his richest, was discovered on August 10, 1578. In about two weeks, using primitive tools of breakage and without the benefit of explosives, 60 miners loosened and loaded 455 tons of ore on to seven small vessels for return to England (E Sellman in Stefansson and McCaskill 1938, 2, 65-70). No evidence was found for fire-setting (Collins 1893; Hoover and Hoover 1950, 118-120). In 1578, this method of rock shattering was probably not used in terrain well beyond the tree line, and with imported fuel in short supply.

Fire assays of ore from this mine were made on a tiny islet which, in the summer of 1578, was headquarters of the mining expedition and was called Countess of Warwick Island, but which today is known as Qallunaaq or Kodlunarn Island (Fig 1). Edward Fenton reported that tests of various types of ore were made during six days in mid-August, 1578 (Kenyon 1981). The results were recorded by the registrar, Edward Sellman, but data have not survived. In fact, it is doubtful whether the registrar's report ever reached England, Frobisher being unable to produce it on demand (Lok 1581a, f. 12r). It appears, however, that on return to England, Robert Denham, who had been chief assayer on the voyage, still held high hopes for the mines: he reported to Michael Lok, the Cathay Company treasurer (Lok 1578), that the summer's ore should average 'almost an once of gold in C of ewer' [1 oz Au/cwt or 20 oz Au/T].

Edward Fenton, the lieutenant-general of the 1578 expedition, took special interest in the mine. It was his mariners who went 'thither to uncover the vaine'. Between August 11 and August 25 he made ten tours of inspection and acted as mine manager, loading supervisor and deputy assayer (E Fenton in Kenyon 1981, 194-99). It was on Fenton's advice that Frobisher christened the mine Countess of Sussex in recognition of Lady Frances Sidney, Countess of Sussex, who had pledged £140 but, as it turned out, never paid a penny to the enterprise (Lok 1581b, ff. 319, 321).

What was Fenton's special interest? The answer may lie in the friction that was rapidly developing between Frobisher and Fenton (Lok 1581a). Neither was in supreme command of the expedition; each occupied an almost equal position: Fenton, the lieutenant-general, in charge of a

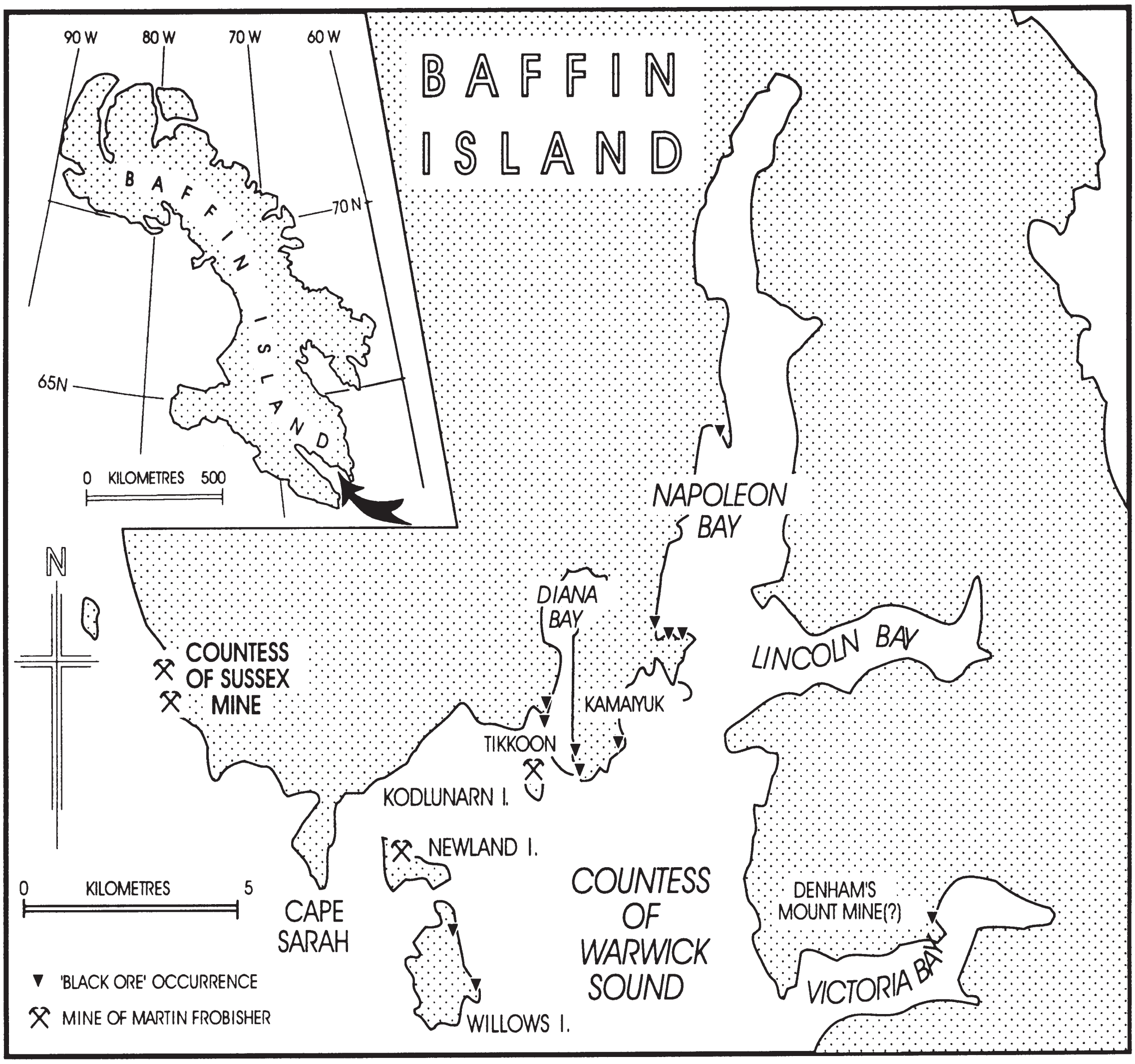


Figure 1: Mines and 'black ore' occurrences, Countess of Warwick Sound, Baffin Island

company of 100 that had first been planned as a colonization force, Frobisher, the admiral, in charge of the remainder. Each had to report to the commissioners of a loosely bonded and unchartered company (Shammas 1975). With two 'bosses' of strong character, each involved in accomplishing difficult tasks under extremely trying circumstances, it was inevitable that, sooner or later, trouble would erupt. At the time of discovery of the Countess of Sussex deposit, Frobisher was busy bringing to production his own mine at Beare Sound, 50 kilometres to the south east, and Fenton may have wished to go one better. Fenton was then smarting from his failure to open a mine at 'Fenton's Fortune', midway to Beare Sound, which had turned out to be minuscule, with low-grade ore, remote and almost impossible to mine. No doubt he looked forward to re-establishing his shattered image.

The Countess of Sussex Mine faded from human memory after it was abandoned at the end of the month. It was only in August 1985 that the occurrence was rediscovered by D D Hogarth and W A Gibbins for the Canadian Department of Indian Affairs and Northern Development, during a brief helicopter search for carving stone and historic sites (Hogarth 1985; Hogarth *et al* 1994). It was easily located from rather precise Elizabethan descriptions: on the east side of Wiswell Inlet, about 5.5 km north of the tip of Cape Sarah, and on a peninsula (in truth across two adjacent peninsulas as land 'adjoyninge to the Maine'). An occurrence, probably representing a Frobisher mine and loading site, was quickly examined on the ground shortly before the whole area was enshrouded in thick Arctic fog. To the outside world the mine had lain hidden for more than four centuries. Further examinations were made by Hogarth in 1990 and 1992, and Hogarth and D Ala in 1991, as members of a Smithsonian interdisciplinary research group.

Geology, mine and ore

Black ore, the term used by Frobisher's men for the black, hard, heavy rock of the Baffin area, believed to contain gold, is attenuated into long tapering lenses in a layer of hornblende - diopside - enstatite - labradorite, incoherent gneiss ('mafic gneiss'). This layer, 5 to 20 metres wide, is sandwiched within hard, grey biotite gneiss and can be traced 1400 metres across two peninsulas (Fig 2). Individual *black ore* lenses are up to 50 metres long and 6 metres wide.

Mining was most active along 220 metres of the south peninsula, where spoil heaps around five shallow surface scrapings can be easily identified. Their maximum elevation is scarcely 6 metres above high tide. These workings terminate abruptly at the north end of this peninsula in two trenches inclined towards tidewater. The 'mines' were dug to a maximum depth of a few metres. Narrow dykes of coarse-grained pink granite ('pegmatite') were not touched, and stand up like walls; in places they separate pits put down in ultramafite. The ore was transported in wicker baskets, itemized in the company's accounts, and perhaps in a man-drawn cart (a 'druge'), also itemized. The route was along the flats immediately east of the ridge of pits: it can be followed by trails of small pieces of *black ore* that spilled from the baskets. Most ore was transported northward, but ore from the southernmost pit was taken to a loading site to the south. The present

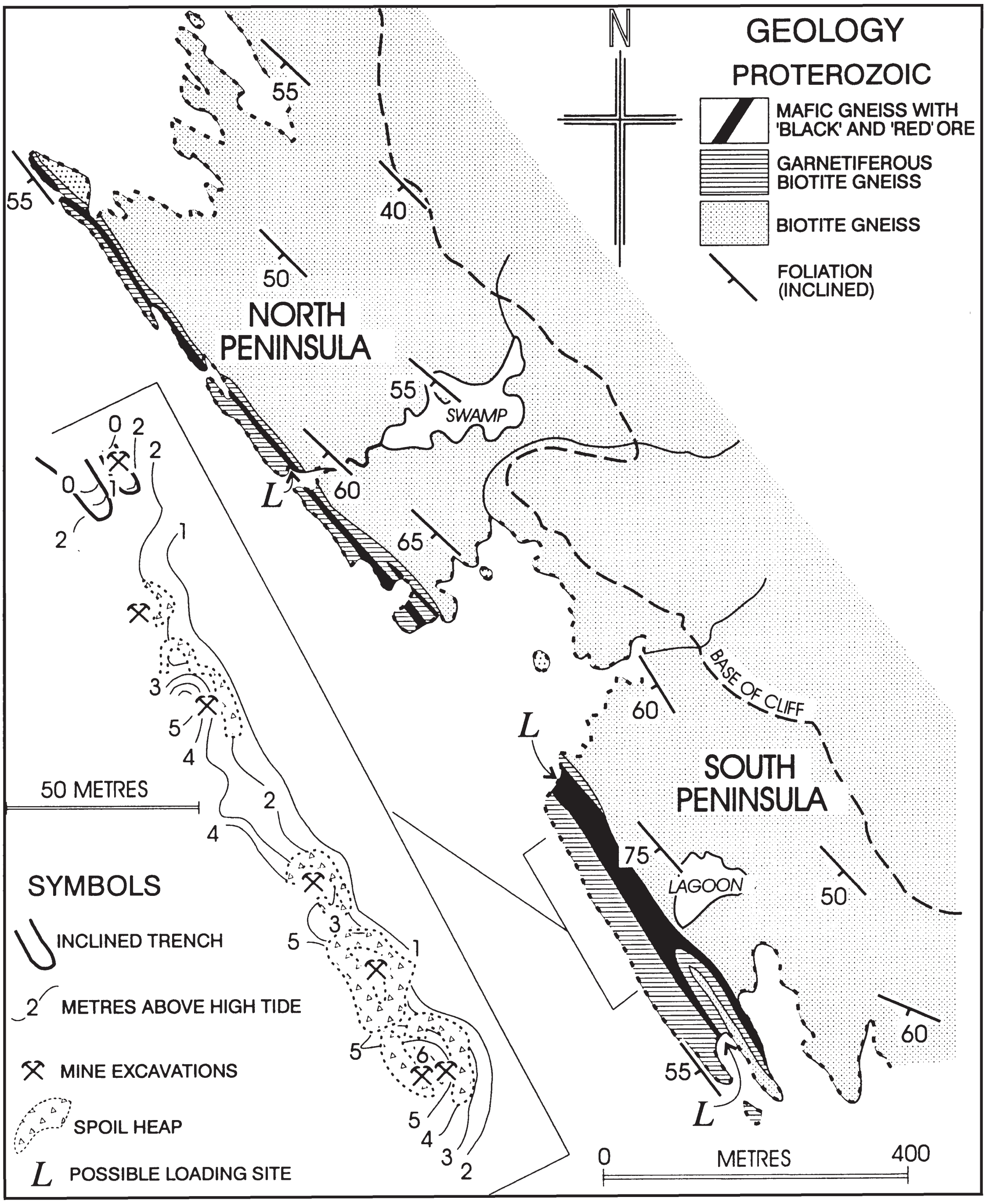


Figure 2: Countess of Sussex Mine; excavations and geology

appearance of the mine must be almost identical to the scene of September 1578. Additional information on geology and mining can be found in Ala (1992) and Hogarth *et al* (1994).

Seven types of ore, each characterized by a specific mineral association, have been identified at this mine: viz *A1, A2, A3, A4, B1, C6, D2* (Hogarth *et al* 1994), but for our purposes *B1, C6* and *D2* only, need consideration. Type *B1* is an ultramafic rock, composed of hornblende-forsterite-enstatite. Type *D2*, another ultramafic rock, is composed of diopside-enstatite-chromian hercynite and grades into *B1*. They are by far the most common *black ores*. Type *C6* is a mafic rock and is composed of hornblende-almandine-andesine. It is reddish black, due to the presence of pink garnet (almandine) in hornblende, and is believed to represent *red ore* which, at the beginning of operations here, was quickly gathered and loaded into the galliass *Ayde*. After the high-grade assay of *red ore* from 'Jonas Mount' in 1577 (B Kranich in Stefansson and McCaskill 1938, 2, 139), company officials held this ore in great esteem, but this valuation seemed to dwindle after the first assays of Countess of Sussex ore (whose data have not survived). There is no further mention of this variant after August 15, but considerable *C6* is still evident on the hanging wall (west side) of the western trench.

The common *B1-D2* ore is characterized by a peculiar hornblende that is tan-brown in plane-polarized light, with a composition approaching magnesio-hastingsite, ideally $NaCa_2Mg_4Fe^{3+}Si_6Al_2O_{22}(OH)_2$ (nomenclature of Leake 1978). The rock is commonly, but not universally, layered and in many samples contains 'strings' of coarse-grained chromian hercynite. Similar rock has been found at Smerwick Harbour, Ireland, where one of Frobisher's noncommissioned ships unloaded in 1578 (Hogarth and Roddick 1989) and Dartford, England, where ore was stored in 1578-79 (Hogarth *et al* 1994).

The coherence of *B1* ore from Baffin, Smerwick and Dartford, with respect to certain elements in the bulk rock and hornblende, is shown in Figures 3 and 4. Compared with Kodlunarn *C1* ores, the *B1* bulk-rock compositions are richer in titanium, chromium and nickel, somewhat

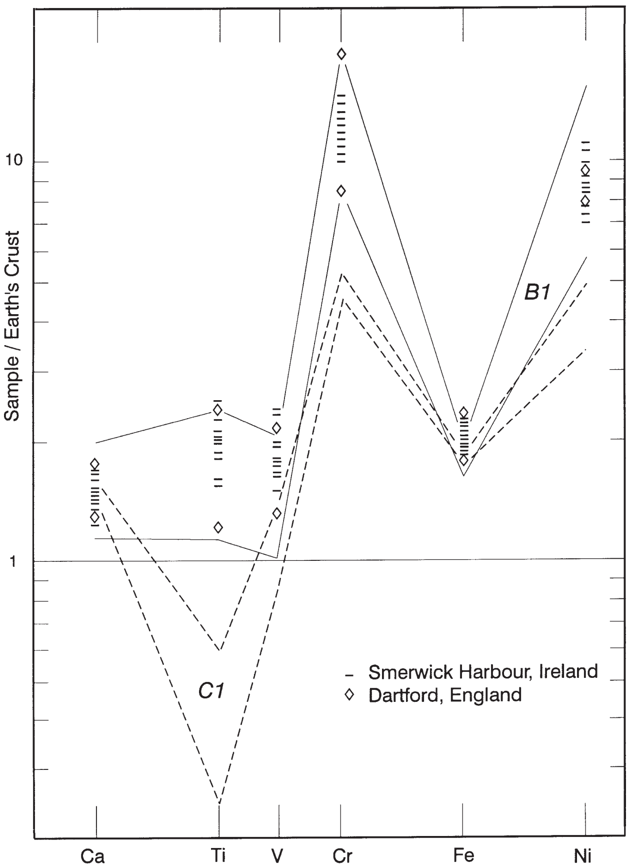


Figure 3: Bulk rock compositions. Specific elements (horizontal axis (interval of atomic numbers) v abundance (normalized to crustal values). B1 compositions, within the solid lines, were defined by twelve B1 and D2 compositions from Countess of Sussex Mine ores. Compositions of Dartford and Smerwick Harbour B1 specimens have been superimposed to show coherence within the rock type. The C1 domain (Kodlunarn Island) is shown for comparison. Analyses by XRF.

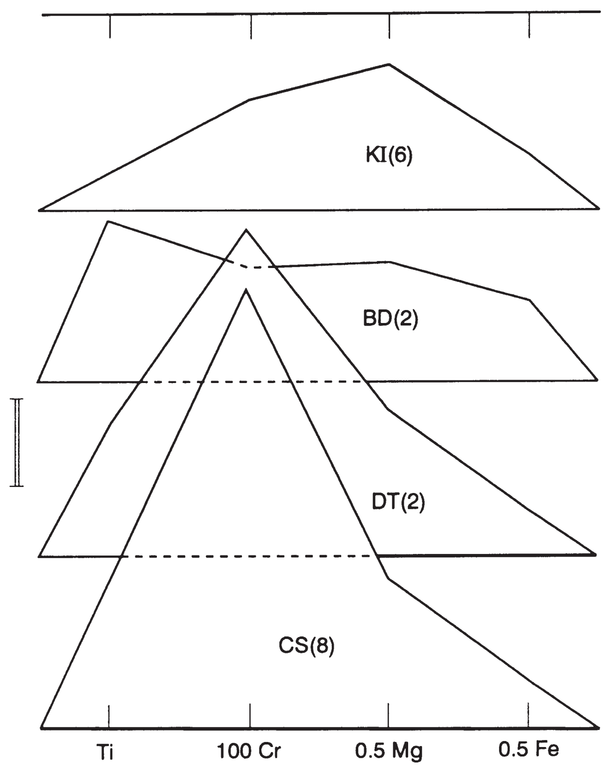


Figure 4: Hornblende compositions. Elements v atoms per standard formula unit; vertical bar represents one atom. Polygons with similar shapes have similar compositions. Abbreviations: BD: erratics on Kodlunarn Island A1 ore, CS: Countess of Sussex Mine B1 ore, DT: Dartford B1 ore, KI: Kodlunarn Island C1 ore. Numbers in parentheses signify numbers of polished sections considered. Analyses by WDS electron microprobe.

Table 1: Analyses of samples collected at or probably derived from Countess of Sussex Mine, Baffin Island

No.	Sample	Type	S_T(%)	Au(ppb)	Ag(ppb)	Pt(ppb)	Pd(ppb)	Method	Locality
wallrock (mafic gneiss)									
1	371	-	<0.01	<1	<500	<10	7	1	C.S. Mine, N. pen.
2	374	-	0.19	<1	<500	<10	5	1	C.S. Mine, N. pen.
3	377	-	0.01	<1	<500	<10	<1	1	C.S. Mine, N. pen.
4	379	-	0.14	<1	500	<10	<1	1	C.S. Mine, S. pen.
5	CS2	-	0.04	<1	<500	-	-	2	C.S. Mine, N. pen.
black ore: (ultramafite)									
6	73b	*B1*	0.13	9	-	<5	5	3	C.S. Mine, S. pen.
7	131	*B1*	0.03	<1	-	<5	2	3	C.S. Mine, N. pen.
8	373	*B1*	0.08	<1	<500	19	8	1	C.S. Mine, N. pen.
9	378	*B1*	0.14	<1	<500	10	5	1	C.S. Mine, S. pen.
10	CS1	*B1*	0.17	<1	-	<15	11	4	C.S. Mine, N. pen.
11	E23e	*B1*	0.02	<50	-	-	-	5	Dartford, U.K.
12	S3	*B1*	0.38	<1	-	<15	7	4	Smerwick, Eire
13	S4	*B1*	0.07	<1	-	<15	2	4	Smerwick, Eire
14	S5	*B1*	0.07	2	-	<15	7	4	Smerwick, Eire
black ore: (ultramafite)									
15	69b	*D2*	0.03	16	-	<5	6	3	C.S. Mine, S. pen.
16	73e	*D2*	0.03	3	-	<5	3	3	C.S. Mine, S. pen.
red ore (mafite)									
17	376	*C6*	0.02	4	<500	18	7	1	C.S. Mine, S. pen

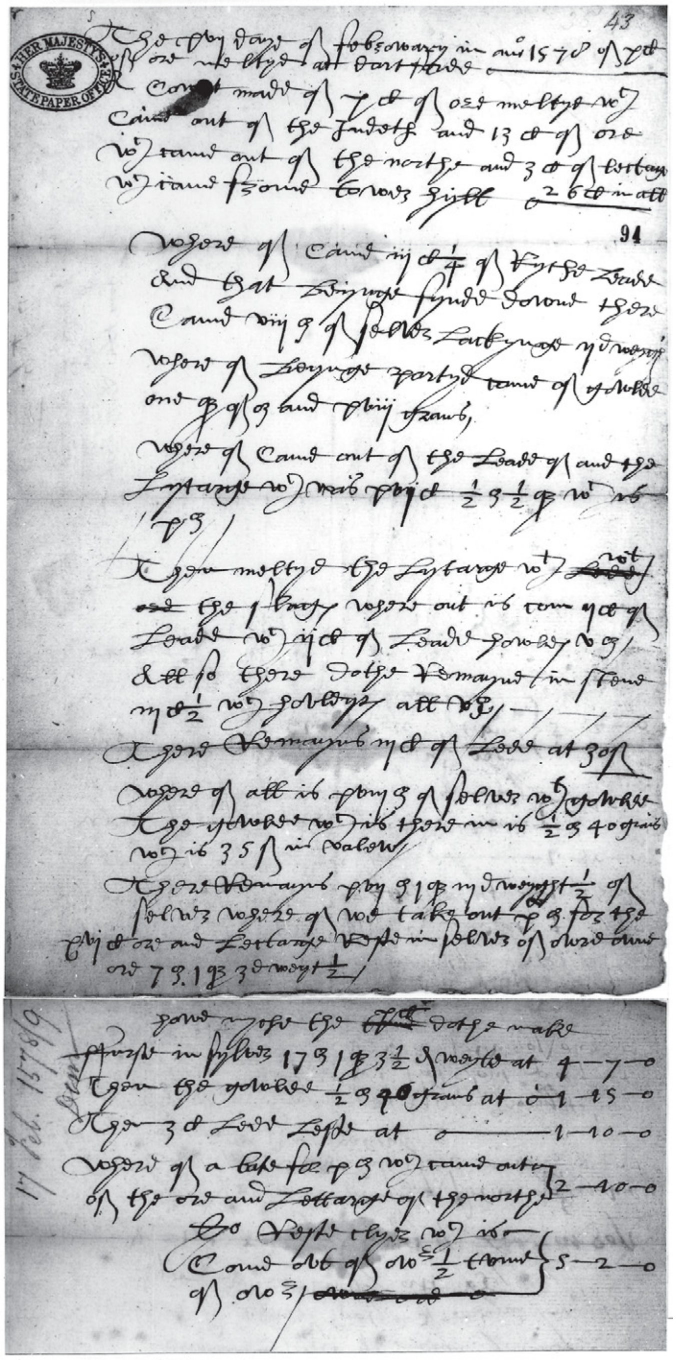
.
Methods: 1 (X-ray Assay Laboratories, Toronto) S: Leco furnace, Au Pt Pd: fire assay-DCP, Ag: atomic absorption; 2 (Univ Ottawa) S: XRF, Au: fire assay-DCP, Ag DCP; 3 (Univ Ottawa) S: XRF, Au Pt Pd: fire assay-DCP; 4 (Univ Ottawa) S: Leco furnace, Au Pt Pd fire assay -DCP; 5 (Nat Hist Museum London) S: Leco furnace, Au: INAA.

richer in vanadium, perhaps slightly richer in iron, but contain the same amount of calcium (Fig 3). The chemical composition of hornblende, the principal mineral, also sets *B1* ores apart. For example hornblende from *B1* of the Dartford suite is similar to that from Countess of Sussex Mine but is rather different from hornblende in *C1* ore and in erratic boulders on Kodlunarn Island (Fig 4). By extending such studies to other rock types, elements and minerals, we can state with some confidence that *B1* ores show a definite chemical coherence and are distinct from other rocks we have studied.

Precious and platinum-group metals

After a lapse of more than four centuries it is opportune to revisit the scenes of industry and test anew the precious metals of the ores with modern methods. Table 1 lists data for 17 samples. Confusion persists on the nature of the ore, which is commonly referred to as 'fool's gold'. This term indicates that the rock is rich in such sulphides as pyrite, pyrrhotite, or marcasite. The column S_T (= total sulphur) is an index of the amount of sulphide present. It is normally <0.15 wt% and does not exceed 0.38 wt% in the samples analyzed, about 1/100 the amount necessary to qualify as 'fool's gold'. Ironically, if sulphides (with which gold is normally associated) had been significant, the gold content would have almost certainly have been higher. Gold here was phenomenally low: ten samples of *B1* and its spinel-rich variant *D2* averaged 3 parts per billion (ppb), a surprisingly low content for ultramafic rock, even lower than the mean content of the earth's crust (given as 3.5 ppb by Li and Yio 1966).

In the sixteenth century, gold was possibly confused with platinum metals, which were not then recognized but would have been concentrated in the fire assays. Our analyses do little to explain the high returns of the Elizabethan assayers. By including the analysis of *C6* ore (No 17) with those of *B1* (Nos 8, 9), the mean platinum and palladium contents are 16 (5) and 7 (2) ppb, respectively. Detectability of silver (500 ppb) was too high for an accurate analysis, but the value <500 ppb is far removed from the 35 to 60 parts per million (ppm) reported by Jonas Shutz and Burchard Kranich.



The xvij daye febrowary in an° 1578 of x C
of ore meltyd at dartforde ○————
A Cownte made of the x C of ore meltyde, w^ch^
Came out of the Judeth, and 13 C of ore,
w^ch^ came out of the northe, and 3 C of lectage,
w^ch^ came frome tower hyll ○——— 26 C in all.

Where of Came iij C¼ of Ryche Leade,
And that beynge fynde downe there
Came viij oz of selver Lackynge ij d weyght.
Where of beynge partyd came of gowlde
one qr of oz and xviij grains.

Where of Came out of the Leade of [sic] and the
Lytarge, w^ch^ was xcj C, ½ oz [per] ½ qr, w^ch^ is
x oz.

Then meltyd the Lytarge w^th^ w^th^ [repeated]
The slags, where out is com ij C of
Leade, w^ch^ ij C of Leade howlds v oz.
All so there dothe Remayne in stone
iij C ½, w^ch^ howdyth all v oz.
There Remayns iij C of Lede at 30 sh,

Where of all is xviij oz of selver w^th^ gowlde.
The gowlde w^ch^ is there in is ½ oz 40 grains
w^ch^ is 35 sh in valew.

There Remayns xvij oz 1 qr iij d weyght ½ of
selver, where of we take out x oz for the
xvj C ore and Lectarge. Reste in selver of owre owne
ore 7 oz 1 qr 3 d weyt ½.

howe myche the x C dothe make	
Furste in sylver, 17 oz 1 qr 3½ d weyte at	4 - 7 - 0
Then the gowlde, ½ oz 40 grains at ○——	1 - 15 - 0
Then 3 C Lede Lefte at ○——	1 - 10 - 0
Where of a bate for x oz w^ch^ came oute of the ore and Lettarge of the northe.	2 - 10 - 0
So Reste clyr w^ch^ is Come out of ow^r^ ½ tunne of ow^r^.	5 - 2 - 0

Figure 5: Assay of Countess of Sussex Mine ore, February 1579

Table 1 includes a sample of *red ore-C6* (No 17) and 5 samples of mafic gneiss (Nos 1-5), which envelops the *black ore*. None of these samples contains significant gold, silver, platinum or palladium and would have little effect if mixed with the *black ore*.

Jonas Shutz and his assay of February 1579

In the sixteenth century fire assaying was a well developed art (see G Agricola in Hoover and Hoover 1950, esp 219-65). The procedure was particularly well advanced in Germany, and German furnace-men were often employed in England during the reign of Elizabeth. Thus, it is not surprising to find Jonas Shutz, 'goldfiner' from Saxony, in charge of most furnace operations of the Frobisher enterprise during its peak activity (1577 to 1579). He used lead (crucible) fusion, followed by bullion concentration in bone ash cupels, nitric acid dissolution of silver in the bead, and precipitation of silver with sodium chloride (common salt), much the same as in fire assays today. But before we exonerate him of all responsibility for the grossly inflated assays, the bulk test of Countess of Sussex ore should be examined critically.

The half-ton assay begun January 20, 1579 (ns) is the one in question. It represented the cargo of the *Judith*, which brought back 60 tons of ore (official weight) all from Countess of Sussex Mine. Jonas Shutz, the master assayer, and Martin Frobisher, leader of the northwest enterprise, were the only officials present during the test (Lok 1581a: 12V). It was recorded February 17, 1579 (ns) in rough draft (with deletions) in what is believed to be the hand of Jonas Shutz. The assay sheets are preserved amongst the State Papers (as SP12/129/43) and are here shown in photograph and transcript as Figure 5. This transcription revises those in Collinson (1867, 204-205) and Stefansson and McCaskill (1938, 2, 149-50). The Julian calendar was used in 1578-1579. Thus February 1578 became February 1579 in the new style, Gregorian calendar. For 'xvij', 'x' [lower case, roman numerals], etc in the transcription, read '17', '10', etc; for 'C' [capital] read 'hundredweight[s]'.

The additive (*additament*) was largely derived from Caldbeck, Lake District, where it had been selected by Frobisher's assayer Robert Denham in November-December 1578. Galena ('lead ore') was transported by the horse-load from Keswick to London, shipped to Dartford and carted to the metallurgical plant on the Darent, three kilometres south, an arduous and expensive process. Some chalcopyrite(?), variously termed *copshredds*, and *copslighe*, may have been included in the furnace charge. Litharge was barged from the Tower, down the Thames, and carted from the Dartford docks to the plant (Lok 1581b, ff. 183-86). The applicability of sulphides, at the crucible stage, is unclear. They were probably deleterious, particularly with silver, which is rather easily sulphidized. Unfortunately, details of the furnace operation are lacking and we do not know whether the galena was treated beforehand.

Shutz first records precious metals in the regulus of the cupel: 7.9 oz silver and gold, parted as 7.61 oz silver, 0.2875 oz gold (Fig 5, lines 7-11). To this is added 5.00 oz silver from the slag (l 15-19), and then he adds precious metals in unpoured lead from the crucible stage (l 20), presumably with the same ratio gold:silver as in the regulus, which by calculation is 0.0375 ounces gold, 5.55 ounces silver. The grand total of silver (18.16 oz) is roughly the same as that given by Shutz (18 oz; l 21) but gold given as 0.583 oz (l 22) is 44% above the recalculated value from data given at the beginning of the assay. The value of silver in the raw additive was then subtracted. At the rate of 0.5 ounce per quarter (l 13), this would amount to 64 ounces in 16 cwt (not 10 ounces as given in l 14, 25 and 32). The value given in this subtraction (50 sh) indicates silver only in the additive (silver was then worth 5 sh, gold 60 sh per oz).

Regardless of the ingredients of the furnace charge (whose effectiveness is suspect) and the capability of the furnace (questioned by Shutz himself), the calculations are fraught with error and the assay is misleading. The amount of gold, calculated from the faulty concluding data as 1.2 oz per ton (l 30, 31), at once indicates something very wrong: it is 10,000 times that of our analyses, checked by several operators, using various methods.

The assay was registered and sent to the Privy Council on February 21, 1579 (ns). The company lost courage, and hope for a profitable mineral industry vanished. The Dartford works closed soon afterwards, we hear no more of the Countess of Sussex Mine, and the mining escapade came abruptly to an end.

Summary and conclusions

In late summer 1578, Edward Fenton and colleagues opened small quarries on the north shore of Frobisher Bay, Baffin Island. These excavations barely penetrated the surface, but much material remained in view for future development. Although some promise was given by contemporary tests on nearby Kodlunarn, later assays in England gave lower returns, but even these were grossly exaggerated. This lack of gold is hardly surprising considering the rock types involved: meta-mafites and meta-ultramafites that had undergone high-grade (granulite facies) metamorphism and which now contain almost no sulphides (Hogarth *et al* 1994, chapter 5). They are most unlikely candidates for gold ore.

Where were the Elizabethans at fault? Although we cannot rule out fraud or the accidental introduction of contaminated furnace charge, certainly the principal assayers were not up to the task of making a reliable test.

Acknowledgements

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