Stream sediment geochemical evidence for gold mineralisation in Hudson Land (73°10′ to 74°25′N, 21°30′ to 24°45′W), North-East Greenland

Agnete Steenfelt

Open File Series 93/4

March 1993

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
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Stream sediment geochemical evidence for gold mineralisation in Hudson Land (73°10′ to 74°25′ N, 21°30′ to 24°45′ W), North-East Greenland

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Abstract

Recent analyses of stream sediment samples from an area in North-East Greenland showed elevated background and anomalies of the gold pathfinder elements As and Sb as well as a number of Au and W anomalies. The distribution of the anomalous samples suggests the occurrence of an Sb-W-Au mineralisation associated with a major late to post Caledonian fault zone in northern Hudson Land and placer type auriferous mineralisation in the Devonian basin in western Hudson Land.

Introduction

In 1986 the Geological Survey of Greenland introduced multielement instrumental neutron activation analysis ("Au+34") as a routine in the reconnaissance geochemical mapping programme based on stream sediment and water samples. Samples collected in earlier programmes were reanalysed as time and budget permitted. In 1992, 1328 stream sediment samples from an area in North-East Greenland were reanalysed and results for Au, As, and Sb are reported here.

Previous exploration by Nordisk Mineselskab A/S based on analysis of panned stream sediment and rock samples indicated several districts of gold mineralisation in the Caledonian fold belt south and west of the area reported on here (Harpøth et al., 1986; Thomassen, 1990). The present results confirm some of the earlier anomalies but also outline some new and different settings.

General geological setting and mineralisation

The area sampled lies within the Caledonian fold belt (Haller, 1971; Koch and Haller, 1971; Henriksen and Higgins, 1976; Bengaard, 1985; Henriksen, 1985) and comprises Hudson Land and Gauss Halvø (Fig. 1). The Caledonian orogeny affected Archaean and Proterozoic basement gneisses as well as Upper Proterozoic (Eleonore Bay Supergroup) to Middle Ordovician sediments. The main Caledonian deformation and metamorphism, taking place during the Silurian, was accompanied by the intrusion of a number of granite (s.l.) intrusions. Post-Caledonian deformation was characterised by extensive faulting during the Mesozoic and until the Tertiary. A geological map at 1:250 000 scale covering most of the sampled area has recently been published by GGU (Bengaard, 1992).

In Hudson Land and Gauss Halvø faulting resulted in the juxtaposition of rock complexes of different ages: Proterozoic gneisses and schists, Upper Proterozoic to Ordovician shelf and basin deposits, Devonian and Carboniferous continental sediments and minor volcanics, Permian to Tertiary shelf sediments and Tertiary volcanics (Fig. 2).

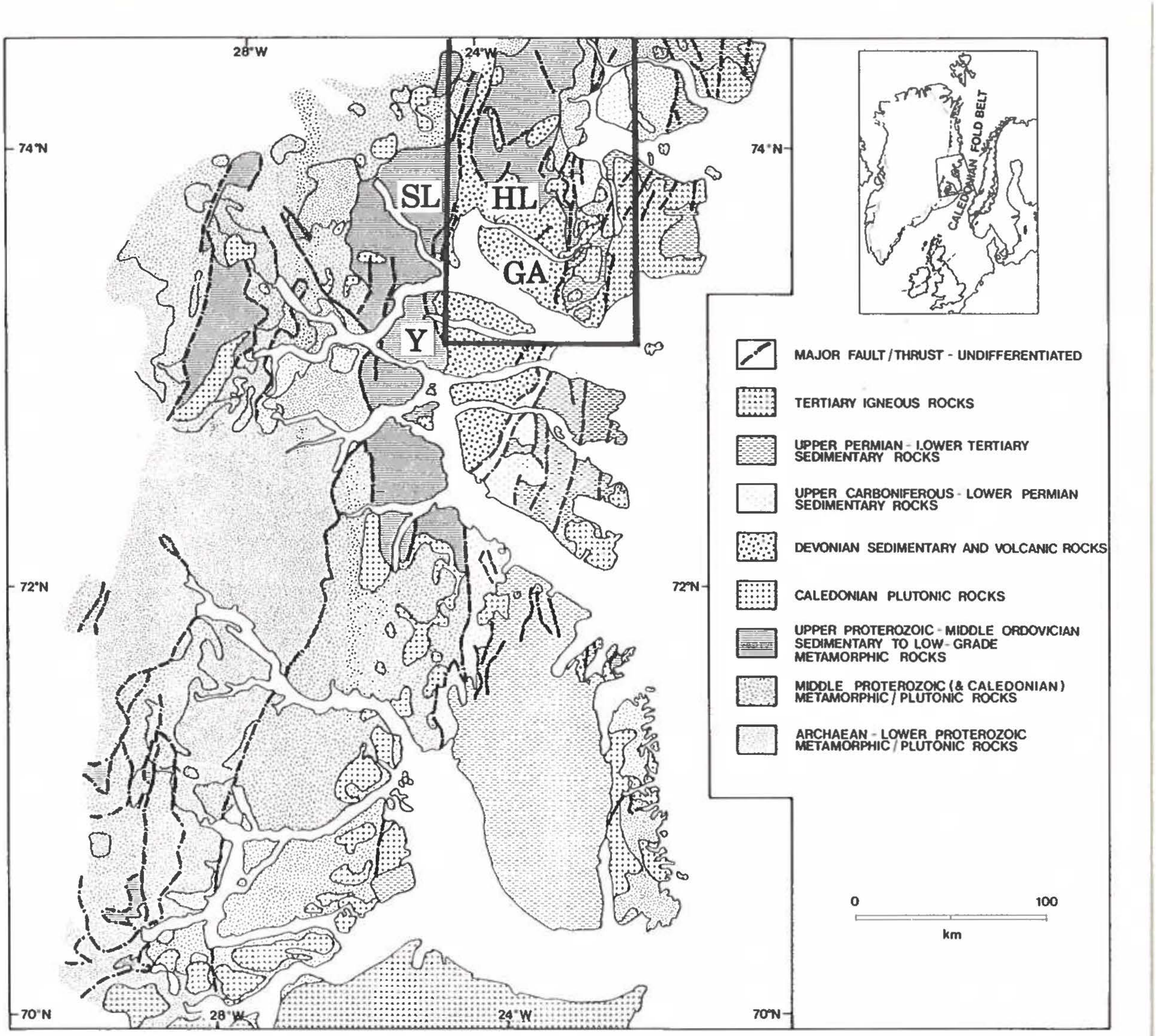

Fig. 1. Simplified geological map of southern North-East and northern East Greenland with sample area (framed). From Harpøth et al. (1986).

HL: Hudson Land

GA: Gauss Halvø

SL: Strindberg Land

Y: Ymer Ø

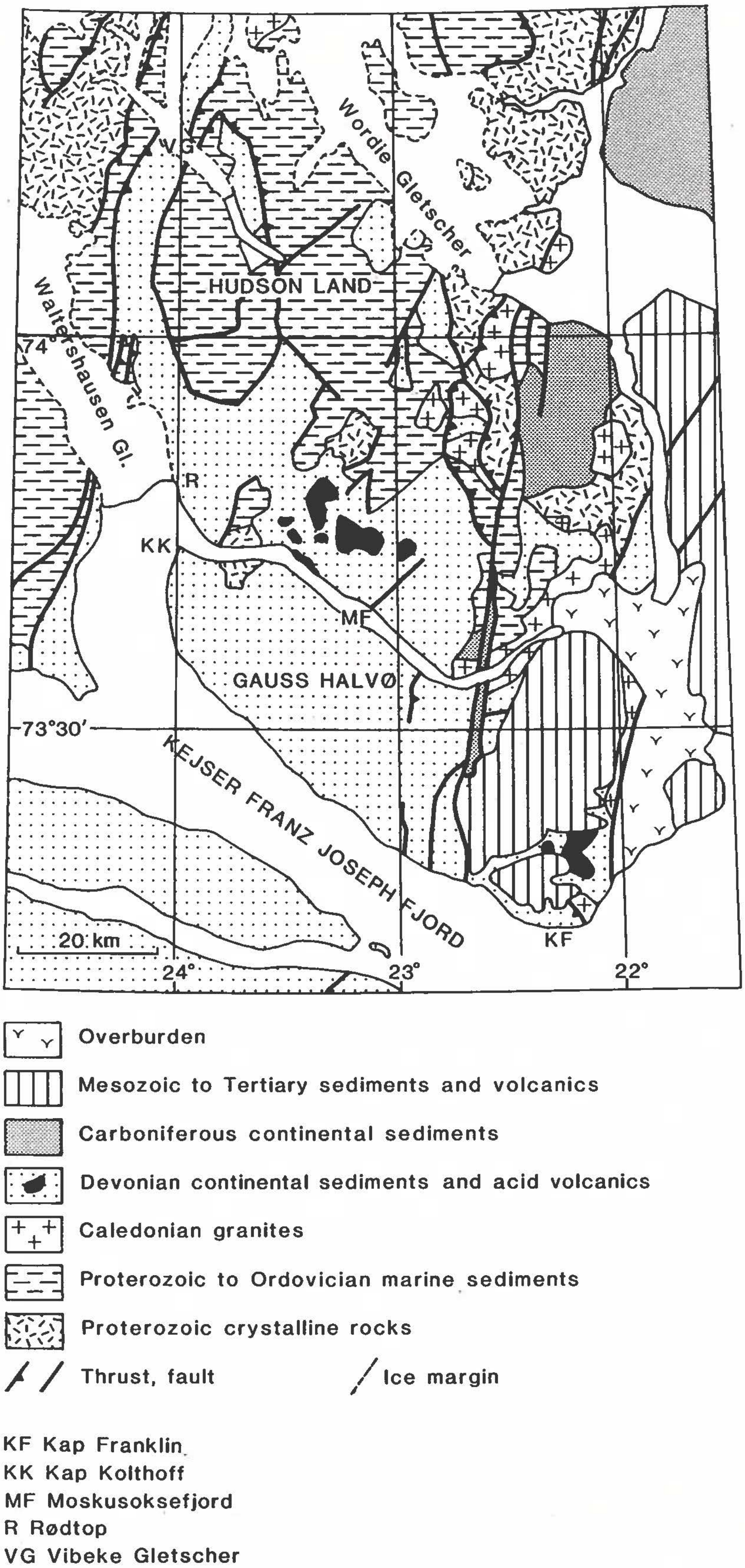

Fig. 2. Simplified geological map of Hudson Land and Gauss Halvø, North-East Greenland. Based on Koch and Haller (1971) and Bengaard (1985).

The N-S faults through western Hudson Land are part of a major zone of sinistral wrench faulting active during the Middle Devonian probably in connection with the initiation of the Devonian Basin (Larsen and Bengaard, 1991). The N-S faults through eastern Hudson Land and Gauss Halvø are part of a major zone of post-Devonian faulting active several times from late Palaeozoic to Tertiary times. The other faults and thrusts in the area (shown in Fig. 2, 3 and 4) are probably of Devonian age (Bengaard, 1985).

A large number of mineral occurrences are known in East Greenland from 70° to 74°30' N due to exploration carried out by Nordisk Mineselskab A/S from 1952 to 1984 and additional investigations made by university groups. From 1971 to 1977 GGU carried out uranium exploration together with supplementary geological investigations in the area from 71° to 76° N. Harpøth et al. (1986) have given a comprehensive inventory of all the mineral occurrences discovered during these activities. Mineralisation was found to have occurred in all major stratigraphical units of the fold belt and the post-Caledonian formations from the Archaean and Proterozoic gneissic basement up to the Tertiary.

In Hudson Land and Gauss Halvø the known mineralisation is associated with Devonian acid intrusive and extrusives rocks (U, F), Upper Permian conglomerate (Cu) and post-Devonian faulting (Cu, Zn, Pb, Ag, Au and U).

Sampling and analysis

Sampling was performed 1975-1977 during a regional uranium exploration programme involving airborne gamma-ray spectrometry (Nielsen & Steenfelt, 1977) and a stream sediment and water geochemical survey. The drainage samples were collected with an average density of 1 sample per 5 km^2. At each stream locality c. 500 g of stream sediment and 1 l of stream water were collected. The sediment was dried and sieved, and the <0.15 mm fraction analysed for U and 10 other major and trace elements. All water samples were analysed for U, and the conductivity was measured; a small number of the water samples were analysed for major compounds. The main results of the geochemical survey were reported by Steenfelt & Kunzendorf (1979).

A number of 1328 samples from Hudson Land and Gauss Halvø were reanalysed for 35 trace elements by Instrumental Neutron Activation Analysis at Activation Laboratories Ltd., Canada.

Results

Abundance and distribution of As,Sb,and Au

Gold was detected in 161, As in 1059 and Sb in 1128 of the 1328 samples analysed. The percentiles are shown in the table below.

Table 1. Abundance and frequency distributions of Au, As and Sb in fine fraction of stream sediment, Hudson Land. Maximum values, area means and estimated average for upper crust (Taylor & Mclennan, 1985) are also shown.

Percentiles	Au ppb	As ppm	Sb ppm
10	0	0	0
20	0	0	0.3
30	0	3	0.4
40	0	3	0.4
50	0	4	0.5
60	0	4	0.6
70	0	5	0.7
80	0	7	0.9
90	5	10	1.3
95	7	15	1.8
98	9	26	3.0
99	9.5	38	3.9
max value	340	190	48
area mean	1.4	5.4	0.7
upper crustal av.	1.8	1.5	0.2

Abundances of As and Sb are high compared to average upper crust. Maps at scale 1:250 000 of the distribution of Au, As and Sb (detection limits are 5 ppb for Au, 2 ppm for As, 0.2 ppm for Sb) are found in the back pocket. A topographical map at the same scale is also included to show terrain and drainage patterns. A geological map at scale 1:250 000 covering the sampled area is available from GGU (Bengaard, 1992).

The 1:250 000 geochemical maps show that slightly elevated values of Au, As and Sb are scattered over the entire area. The high values are also displayed in Figs 3 to 5 where it is seen that high As and Sb are mostly associated with faults within or at margins of occurrences of the Proterozoic to Ordovician sediments (compare with Fig. 2). The highest Sb values occur in a cluster of

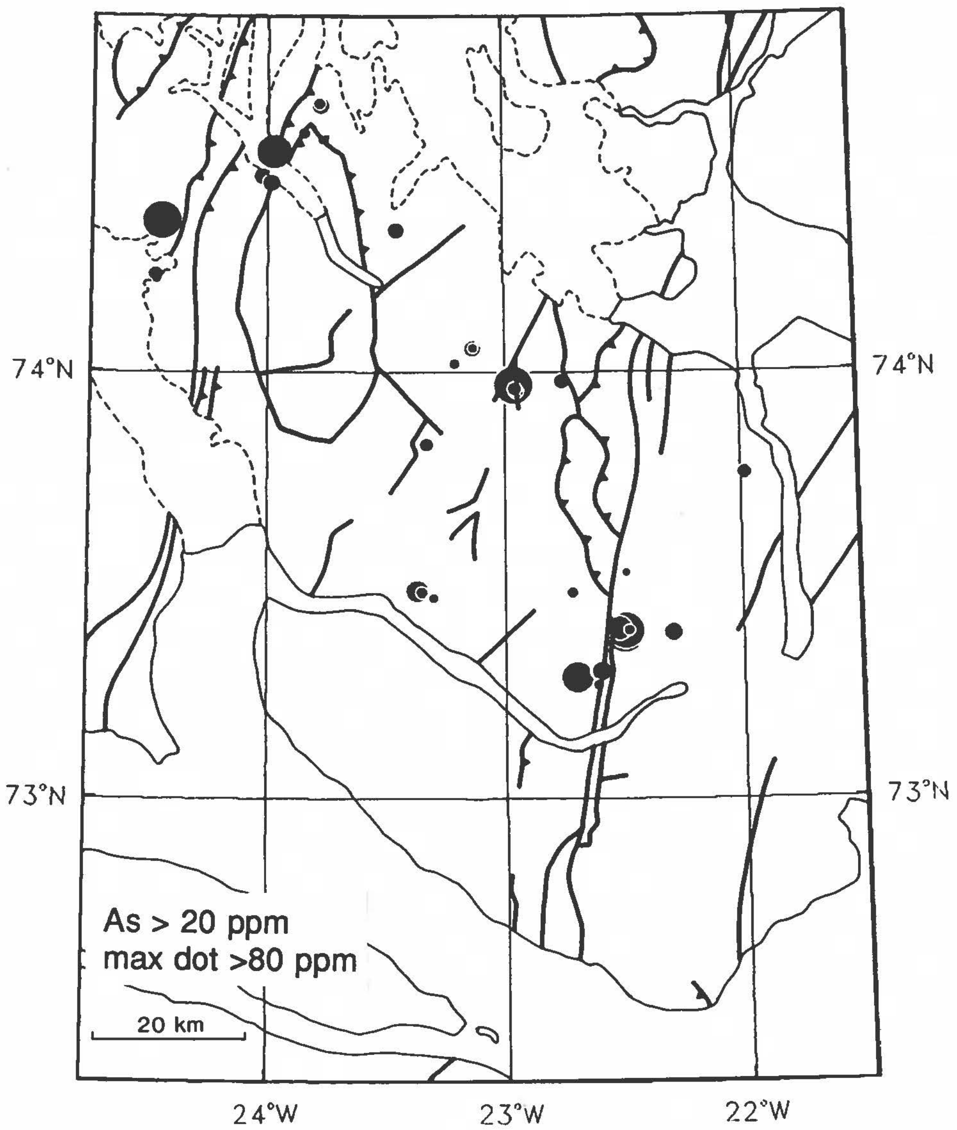

Fig. 3. As anomalies in stream sediment.

combined As-Sb anomalies at the eastern fault of the Devonian graben across Vibeke Gletscher (VG in Fig. 4). In addition, elevated values of Sb and As are associated with Devonian acid volcanics N of Moskusoksefjord (MF in Fig. 4).

High As values are found in the post-Devonian fault system in Eastern Gauss Halvø and Hudson Land.

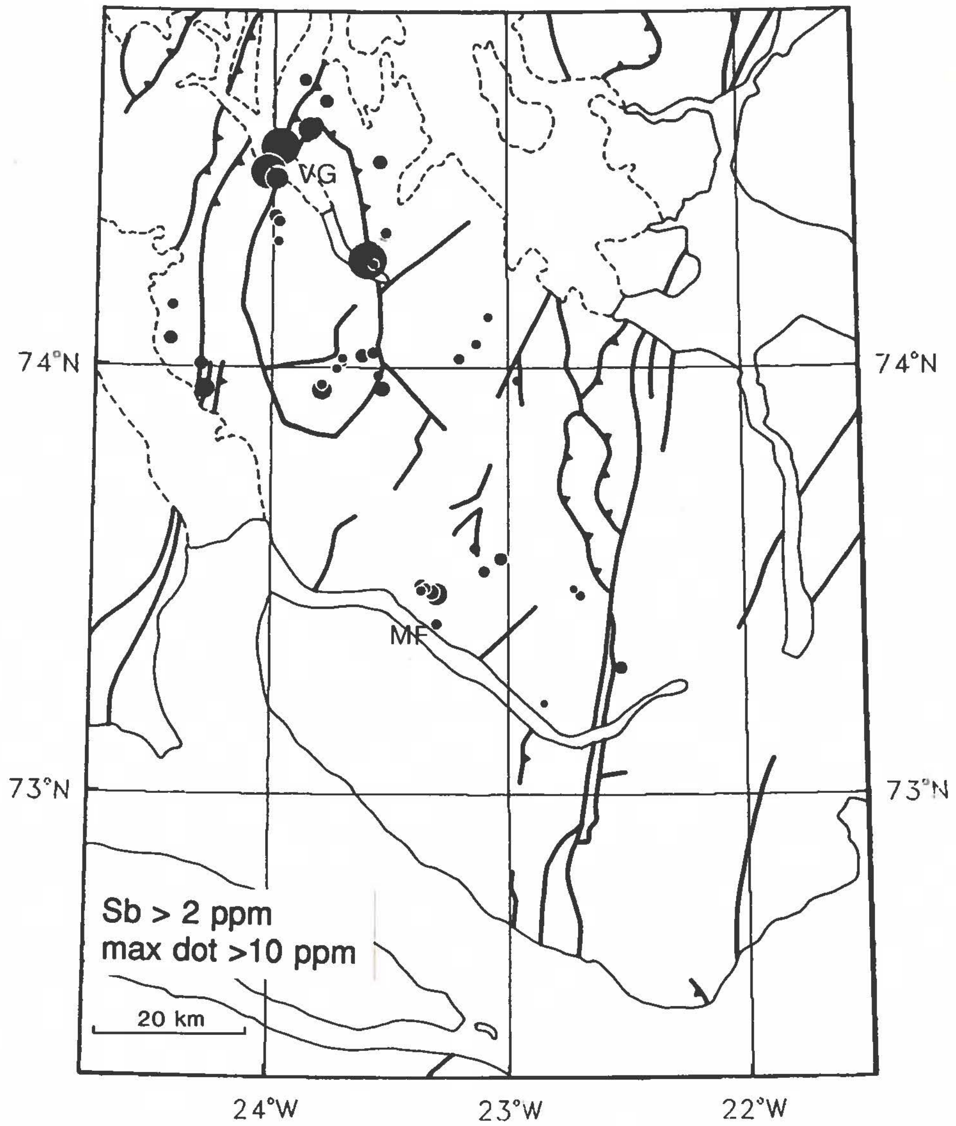

Fig. 4. Sb anomalies in stream sediment.

Only 13 samples in Hudson Land have more than 10 ppb Au. They are shown in Fig. 5. With three exceptions they fall within or at the margins of the Devonian basin. The highest values are part of a cluster of 13 gold containing samples around Rødtop, east of the front of the Waltershausen Gletscher, see 1:250 000 map of Au distribution. The other high values are more scattered over the various outcrops of the Devonian basin from Kap Franklin in the extreme south to the two anomalies at Vibeke Gletscher in the north (VG in Fig. 4). One anomaly is situated within the late Proterozoic sediments north of the Devonian basin and two lie on the eastern major post-Devonian fault zone north of the head of Moskusokseſjord (MF in Fig. 4).

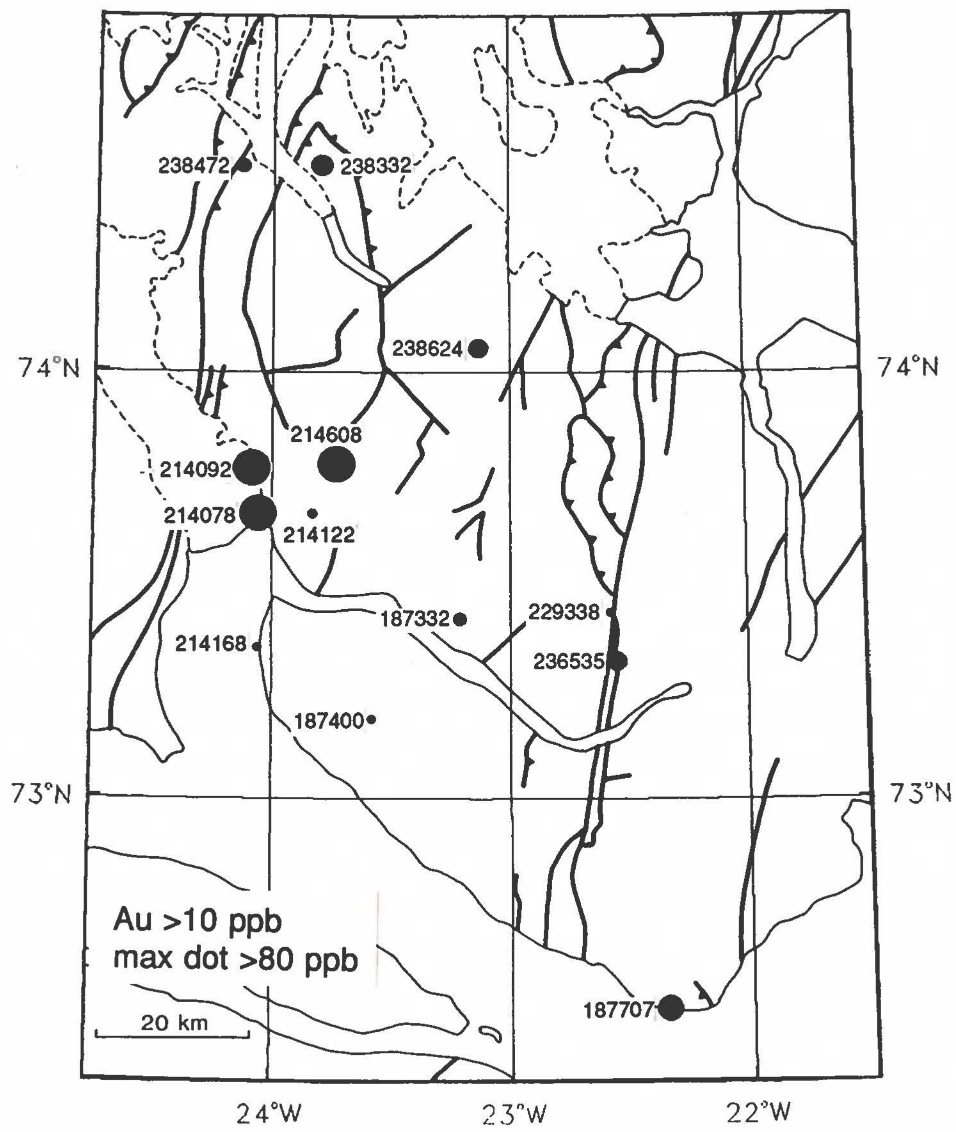

Fig. 5. Au anomalies in stream sediment with sample numbers as in Table 2.

The Au values between 5 and 10 ppb (see 1:250 000 plot) do not form clusters and are apparently not associated with any particular stratigraphic or lithologic unit. They are considered to be part of the local background scatter for Au.

In summary the Au, As, Sb anomalies are predominantly associated with four different settings: 1) The western fault zone forming the boundary between the Devonian basin and the Late Proterozoic to Ordovician sedimentary deposits; 2) The Devonian sedimentary succession; 3) The Devonian acid volcanics, and 4) The eastern post-Devonian fault zone.

Discussion

Eleonore Bay Supergroup and Western Fault Zone

The Upper Proterozoic to Ordovician sedimentary succession comprises the Upper Riphean and Sturtian (c. 950 to 610 Ma) Eleonore Bay Supergroup (EBS), the Vendian (c.610 to 570 Ma) Tillite group and a Cambrian to Middle Ordovician sequence. The lower siliciclastic part of the sedimentary succession was deposited in both continental and shallow marine shelf environments. The deposits in Hudson Land and Strindberg Land, west of Hudson Land, comprise the upper EBS (studied near Vibeke Gletscher by Sønderholm et al., 1989), the Tillite group, and the Cambrian to Ordovician sequence (studied by Hambrey et al., 1989). The depositional environment during the Upper EBS to Ordovician is described as 'predominantly slope and shelf facies, followed by glaciation in a marginal marine setting, then predominantly deeper water turbiditic sedimentation, another phase of marginal marine glaciation, a postglacial phase of shallow shelf to offshore deposition' (Hambrey et al., 1989). The Cambro-Ordovician deposits are predominantly platform carbonates.

The Upper EBS contains several horizons enriched in sulphides, particularly pyrite and Cu-sulphides (Fig. 6) interpreted to be of syn-sedimentary to early diagenetic origin (Ghisler et al., 1980; Stendal & Ghisler, 1984). The mineralised beds are rich in organic matter, and it is quite likely that As enrichment also took place in the bituminous horizons. The mineralisation described in the Upper EBS shows signs of later (local) mobilisation believed to be associated with regional metamorphism (Ghisler et al., 1980).

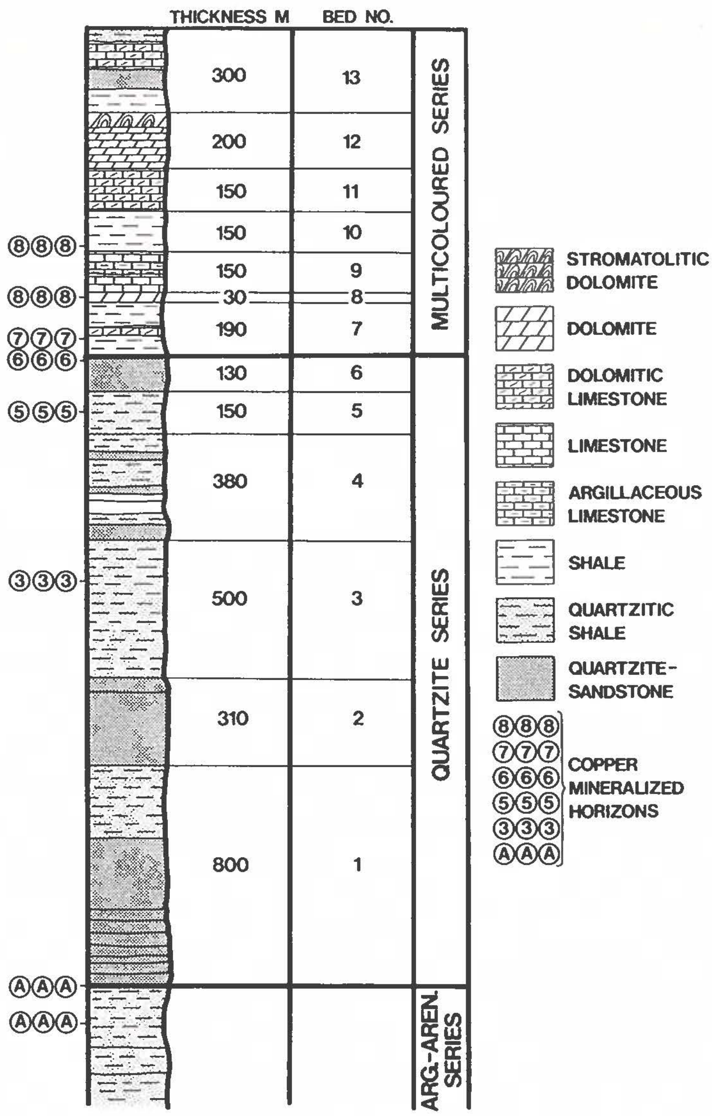

Fig. 6. Stratigraphy and Cu mineralisation in the Upper Proterozoic Eleonore Bay Supergroup. Modified from Ghisler et al. (1980) by Harpøth et al. (1986).

A large number of the known mineral occurrences in EBS is related to late Caledonian granite intrusions and late Caledonian to Upper Devonian faulting (Harpøth et al., 1986). The most significant in relation to Hudson Land is a scheelite-stibnite(-gold) vein mineralisation in the Western Fault Zone at Ymer Ø (Fig. 7), c. 50 km south of Hudson Land (Pedersen & Stendal, 1987). The mineralisation, estimated to contain 120 000 t at 1.8% W and 110 000 t at 3.5% Sb, is located in secondary tensional fractures close to the major N-S faults. It is interpreted to have been deposited from a precious metal bearing, active hydrothermal system (Pedersen & Stendal, 1987). An epigenetic Cu-Sb mineralisation at Strindberg Land just west of the major fault zone is thought to have a similar origin as the Ymer Ø mineralisation (Harpøth et al., 1986).

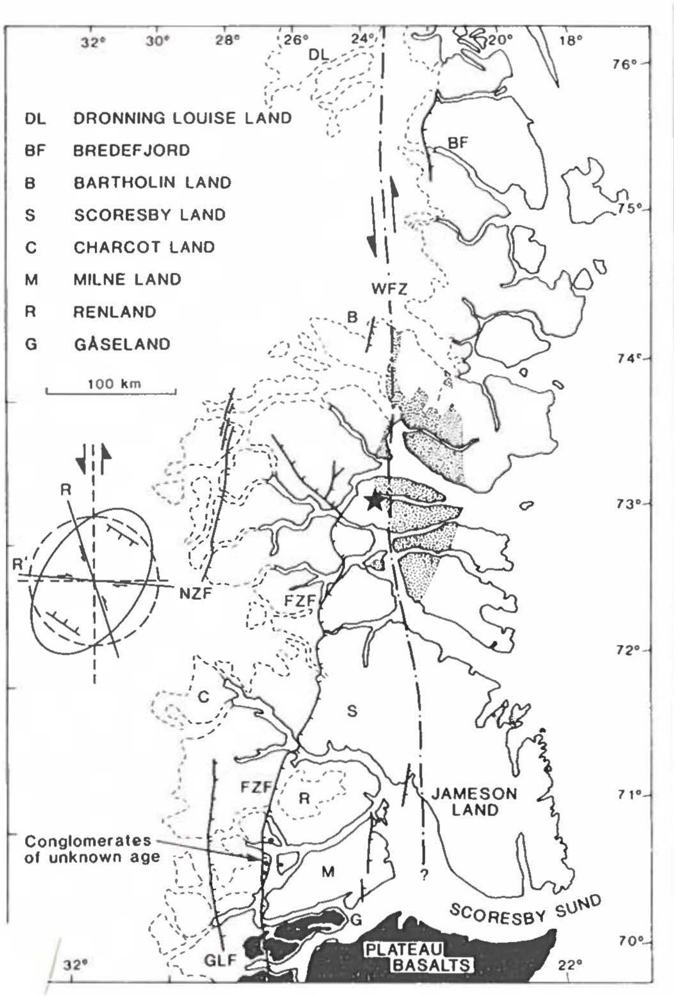

Fig. 7. The western fault zone (WFZ) in relation to the Devonian basin (stippled). From Larsen & Bengaard (1991). The star marks the location of the Ymer Ø Sb-W-(Au) mineralisation.

The geological setting of the area with the Sb anomalies at Vibeke Gletscher in northern Hudson Land is very similar to that of Ymer Ø. The host rocks belong to the same stratigraphical level, they are close to the Western Fault Zone, and there is an outcropping Caledonian granite intrusion less than 20 km to the north of the anomalies, which could have contributed to driving a hydrothermal convecting system in the faults. Furthermore, the Sb-anomalous stream sediments are also anomalous in W (Fig. 8).

The Sb, As, Au and W anomalies along the major western fault system in Hudson Land are, therefore, interpreted to reflect mineralisation of the same kind as encountered at Ymer Ø. The high concentration of Sb (5-12 ppm) in the stream sediment samples suggests that stibnite may be an important constituent.

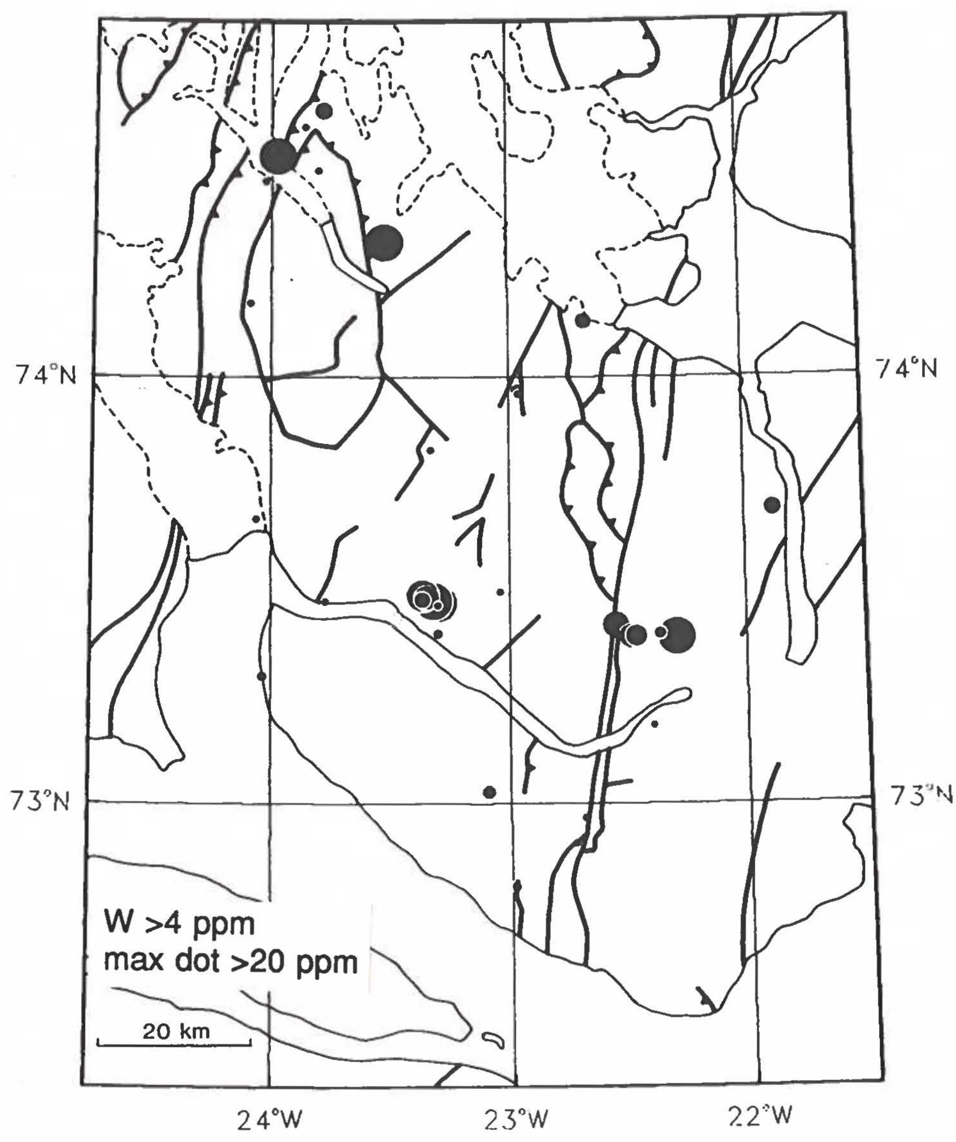

Fig. 8. W anomalies in stream sediment.

The distribution of stream sediment As, Sb and Au anomalies combined with information on mineral occurrences in EBS and the fault zones suggests that synsedimentary enrichment in these elements occurred in the EBS and that subsequent redeposition took place in hydrothermal systems generated by granite magmatism and operating along fault systems.

The Devonian basin

The Devonian continental basin in Hudson Land has been studied by Bütler (1959), Friend et al. (1983), Larsen et al. (1989), Olsen & Larsen (1993) and Olsen (in review). The basin was formed as a result of faulting in the Middle and Late Devonian (Fig. 7) and was filled with fluvial, limnic and occasional aeolian sediments. The general stratigraphy and map is shown in Fig. 9.

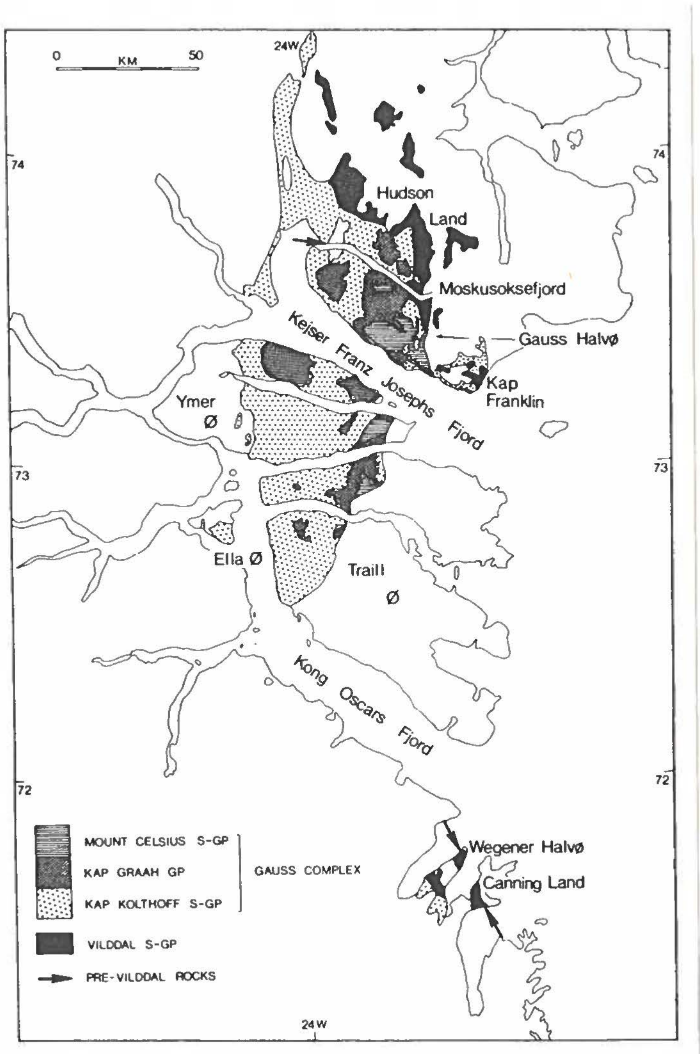

Fig. 9. Stratigraphy and map of the Devonian succession. From Friend et al. (1983).

The samples with high Au concentrations from the northwestern part of the Devonian basin (at Rødtop in Fig. 2) contain slightly elevated but not anomalous values of As and Sb, but many are high in Hf, Th and U (Table 2; Fig. 10). From the first analysis of the stream sediments (Steenfelt & Kunzendorf, 1979) it was already known that elevated U concentrations occurred in this region.

Table 2. Selected element concentrations of Au anomalous stream sediment samples (Au >10 ppb) from Hudson Land and Gauss Halvø, East Greenland. Instrumental neutron activation analysis by Activation Laboratories Ltd.

GGU no	Au ppb	As ppm	Sb ppm	Cr ppm	Hf ppm	Th ppm	U ppm	Ce ppm	Yb ppm
187332	25	2	.4	50	16	8.7	2.5	60	3.36
187400	15	6	.6	35	7	9.2	2.0	63	3.26
187707	54	14	1.2	91	11	10.0	3.2	74	4.16
214078	340	14	.9	53	87	31.0	8.1	280	16.20
214092	175	20	.6	120	280	70.0	20.0	470	33.60
214122	16	0	.8	29	12	17.0	.9	140	6.07
214168	15	15	.0	45	86	29.0	7.4	340	22.70
214608	115	2	.5	50	38	21.0	3.6	160	7.75
229338	14	13	1.7	95	9	12.0	5.4	95	4.37
236535	40	4	.6	50	32	18.0	4.2	130	5.57
238332	45	12	1.0	28	30	15.0	3.2	110	7.40
238472	28	4	.0	22	17	13.0	3.8	110	5.32
238624	40	36	2.6	32	22	14.0	3.6	100	5.96
area mean	1.4	5.3	0.7	53	16	13.7	3.2	99	4.68

Field inspection was made by the author in 1976 at stream sediment uranium anomalies in the Rødtop area, although not in the streams with the highest Au concentrations. It was found that elevated radioactivity was associated with 1 to 2 dm thick, dark rusty horizons with a high proportion of heavy minerals, and such horizons were, therefore, believed to be the cause of the uranium anomalies in the stream sediments (Steenfelt and Kunzendorf, 1978). The presence of the heavy mineral horizons explains the elevated concentrations of Hf, Th, Ce and U in the stream sediments.

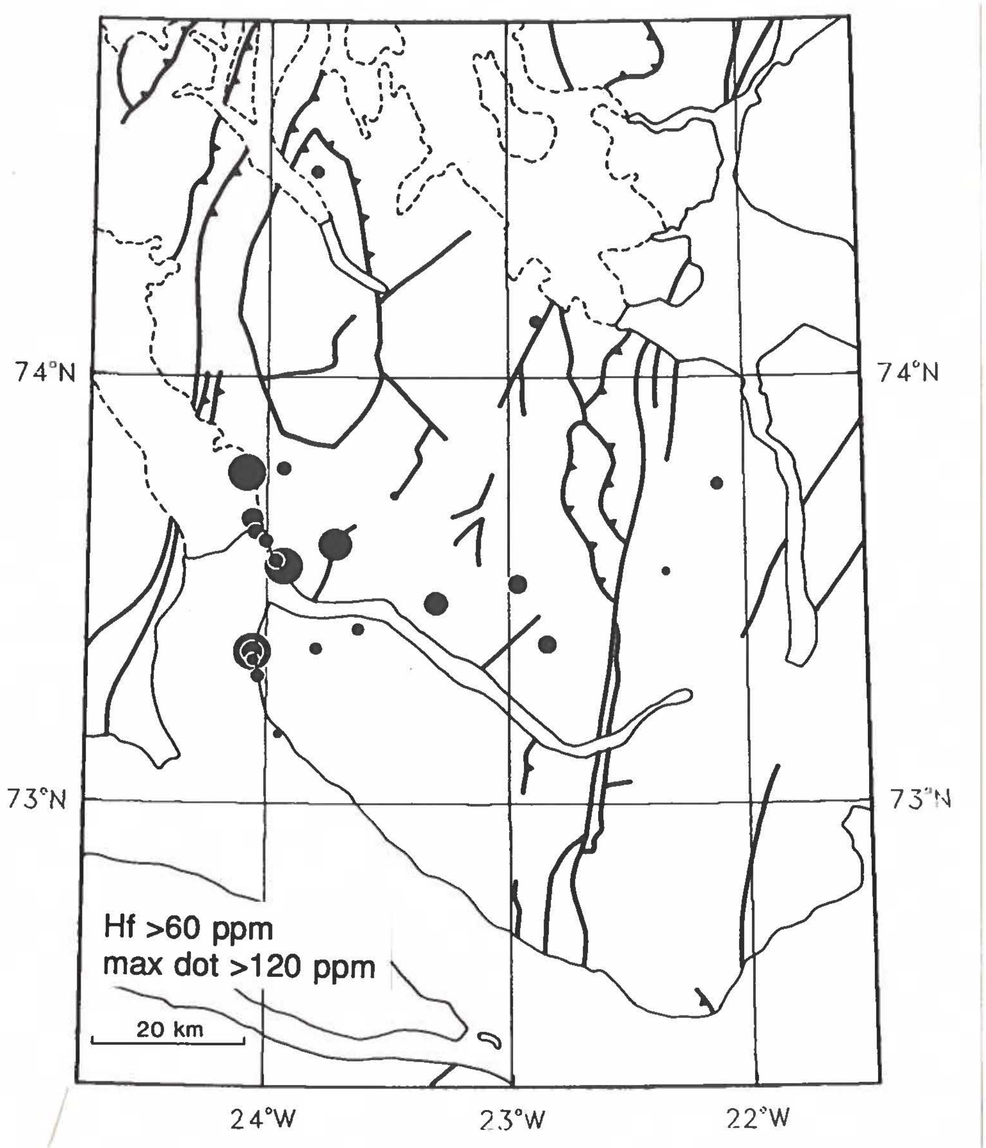

Fig. 10. Hf anomalies in stream sediment.

The horizons with heavy minerals were found in the uppermost part of the Kap Kolthoff supergroup (Fig. 9) at altitudes of 700-900 m a.s.l. The sandstones here are fine grained, light grey with cross bedding and other sedimentary structures indicating a fluvial environment. There are local boulder beds up to 1 m thick with up to decimetre-sized boulders of EBS rocks, granite and gneiss. The rocks are not metamorphosed and commonly loosely cemented. Analyses of rock samples are shown in Table 3. The chemistry reflects the assemblage of heavy minerals: zircon (high Hf), monazite (high Ce), magnetite, ilmenite, Cu-

Zn-Pb-sulphides and pyrite; the As contents suggest presence of small amounts of arsenopyrite. However, gold is not high in the rock samples, which is agreement with low Au in streams draining the rock sampling site.

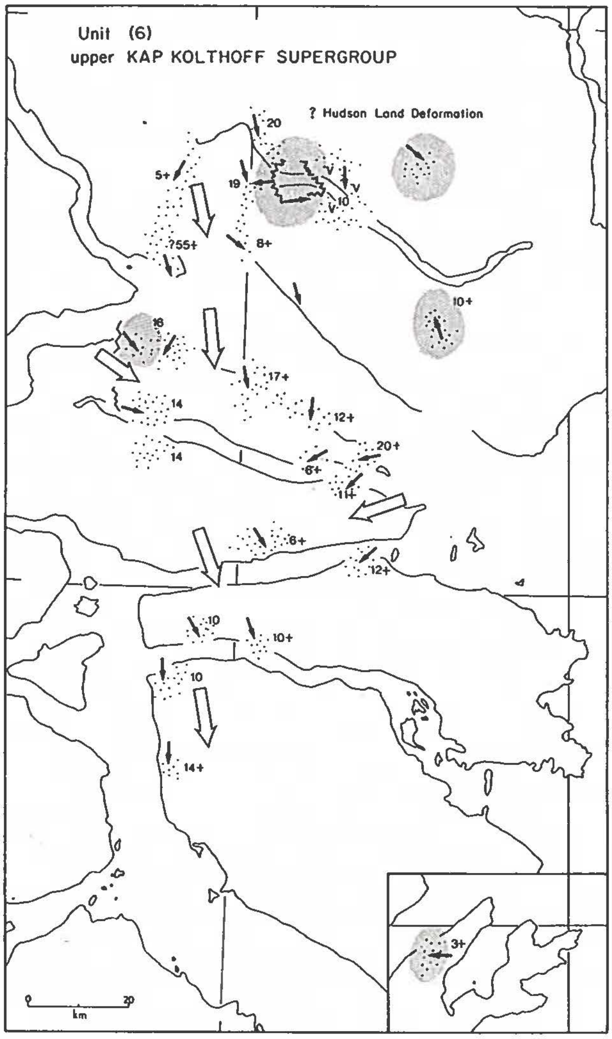

Fig. 11. Summary of palaeogeographic information for upper Kap Kolthoff Supergroup, Devonian basin. Numbers are thickness in hundreds of metres. Arrows are palaeocurrent means for groups of localities. Fine stipple indicates proven underlying unconformity. Coarse stipple indicates fine sandstone. V indicates volcanics. From Friend et al. (1983).

Sedimentological and stratigraphical studies by Friend et al. (1983) and Larsen et al. (1989) indicated that the provenance terrains of the Kap Kolthoff series sediments at Rødtop were highlands to the north and north-west (Fig.

11). These highlands consisted of faulted EBS and crystalline basement which is in agreement with the character of the boulders and the heavy minerals.

Table 3. Element concentrations of rock samples from the Devonian sedimentary succession at Rødtop, Hudson Land, and Kap Kolthoff, Gauss Halvø. Instrumental neutron activation analysis by Activation Laboratories Ltd.

GGU no	Au ppb	As ppm	Ba ppm	Ca %	Co ppm	Cr ppm	Fe %	Hf ppm
226001	0	4	490	0	15	58	10.40	38
226011	0	0	410	6	6	26	1.36	13
226013	10	56	270	0	13	72	11.90	52
226015	10	93	320	5	17	83	15.50	96
226017	9	0	430	10	14	10	0.81	3
226018	14	3	400	1	22	11	0.80	4
226019	9	57	470	6	11	64	12.00	100
226020	9	11	450	0	20	0	1.26	11
226024	8	7	0	0	13	0	0.86	10

GGU no	Rb ppm	Sc ppm	Ta ppm	Th ppm	U ppm	Zn ppm	Ce ppm	Yb ppm
226001	0	54	4	140	16.0	190	830	32.30
226011	63	7	1	18	3.1	0	120	4.25
226013	0	59	4	130	8.7	130	540	35.00
226015	0	66	6	160	13.0	220	580	43.90
226017	67	3	0	4	32.0	0	49	1.39
226018	71	4	2	8	0.0	0	58	1.50
226019	0	52	5	110	11.0	230	600	38.40
226020	380	1	4	51	340.0	88	97	22.20
226024	460	1	4	45	9.6	74	40	8.49

226001	Dark sandstone, Kap Kolthoff Supergroup, Rødtop
226011	Dark sandstone, Kap Graah formation, Rødtop
226013	Rusty heavy mineral zone, Kap Kolthoff Supergroup, Rødtop
226015	Rusty heavy mineral horizon with pyrite and Fe-Mn hydroxides
226017	Red coloured sandstone
226018	Typical sandstone, Kap Kolthoff supergroup
226019	Rusty heavy mineral horizon, Kap Kolthoff supergroup, Gauss Halvø
226020	Uranium and fluorite mineralised rhyolite, Hudson Land
226024	Typical red rhyolite, Hudson Land

The palaeogeographic situation combined with the coincidence in stream sediment between high Au and high concentrations of elements contained in heavy minerals suggest that the gold in the Devonian strata is derived from weathering of auriferous (sulphide) mineralisation probably associated with the major Western Fault Zone. Gold grains or auriferous minerals may have been deposited together with other heavy minerals at suitable sites in the Devonian fluvial systems, e.g. in heavy mineral seams or conglomerates. If this has been the case, the Devonian basin holds a potential for placer type auriferous deposits. There are weak indications of similar placer type mineralisation south of Kap Kolthoff at Gauss Halvø (see Fig. 2 and 4). There is one Au anomaly, stream sediments are enriched in Hf, U and Th, and dark heavy mineral horizons were found (sample 226019 in table 3).

Devonian acid volcanics

A cluster of samples north of the outer Moskusoksefjord (MF in Fig.2) are enriched in Au and Sb. The anomalous streams are draining an area with outcrops of acid volcanic rocks in the upper Kap Kolthoff supergroup (Friend et al., 1983). The rhyolithic lava from this area contains both Au, As and Sb (Table 3), and is considered to be the source of the elevated concentrations in the streams. The acid volcanic rocks were mapped and studied during the uranium exploration survey, as they host late magmatic and epigenetic uranium mineralisation (Steenfelt, 1982). The Au anomaly at Kap Franklin (187707 in Fig.5) is also likely to be associated with Devonian acid volcanics (see Fig.2).

Post-Devonian fault zone

This major fault zone is known to hold several mineralised occurrences with base and precious metals (Fig. 12). Also uranium is enriched in this zone (Steenfelt & Kunzendorf, 1979; Steenfelt, 1982). According to Bütler (1957) the faulting was initiated in the Lower Carboniferous and reactivated during the Mesozoic and Cenozoic. In Hudson Land and Gauss Halvø some of the mineralisation in the fault zone is associated with the intrusion of Devonian high level granites enriched in U, Th, Sn, W and F prior to the faulting. The mineralisation related to the fault structures is hosted in fractures and breccias. The elevated As in stream sediment may either be derived from vein mineralisation or from the rocks of the EBS hosting the faults. The two Au anomalies probably reflect the known breccia type mineralisation (Fig. 12).

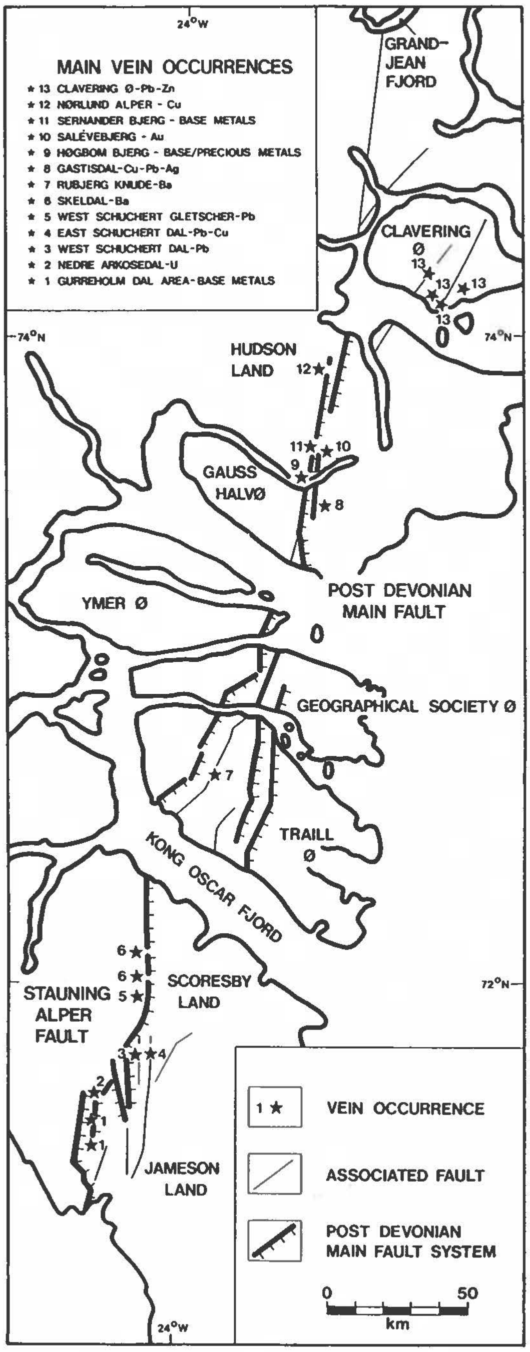

Fig. 12. Vein mineralisation associated with the post-Devonian main fault system. From Harpøth et al. (1986).

Conclusion

The abundance and distribution of Au, As, Sb, Hf and W in the less than 0.15 mm grain size fraction of stream sediment from Hudson Land and Gauss Halvø shows that the late Proterozoic to Ordovician sedimentary sequence is enriched in gold pathfinder elements As and Sb relative to upper crustal average, and that auriferous mineralisation is associated with three different settings in the sampled area: 1) the major late to post-Caledonian fault zone at the western margin of the Devonian basin, 2) Devonian river systems draining this major fault zone, and 3) the post-Devonian fault zone at the eastern margin of the Devonian basin.

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Enclosures

1. Topographical map, 1:250 000 scale, of the sample area.

2. Geochemical map of As in <0.15 mm fraction of stream sediment. Circle radius is proportional with the concentration. Minimum circle size represents 4 ppm or below; Maximum circle size equals 100 ppm As or more.

3. Geochemical map of Sb in <0.15 mm fraction of stream sediment. Circle radius is proportional with concentration. Minimum circle represents 0.02 ppm or below, maximum 10 ppm or more.

4. Geochemical map of Au in >0.15 mm fraction of stream sediment. Circle radius is proportional with concentration. Minimum circle represents less than 5 ppb, maximum 50 ppb or more.

MOSKUSOKSEFJORD

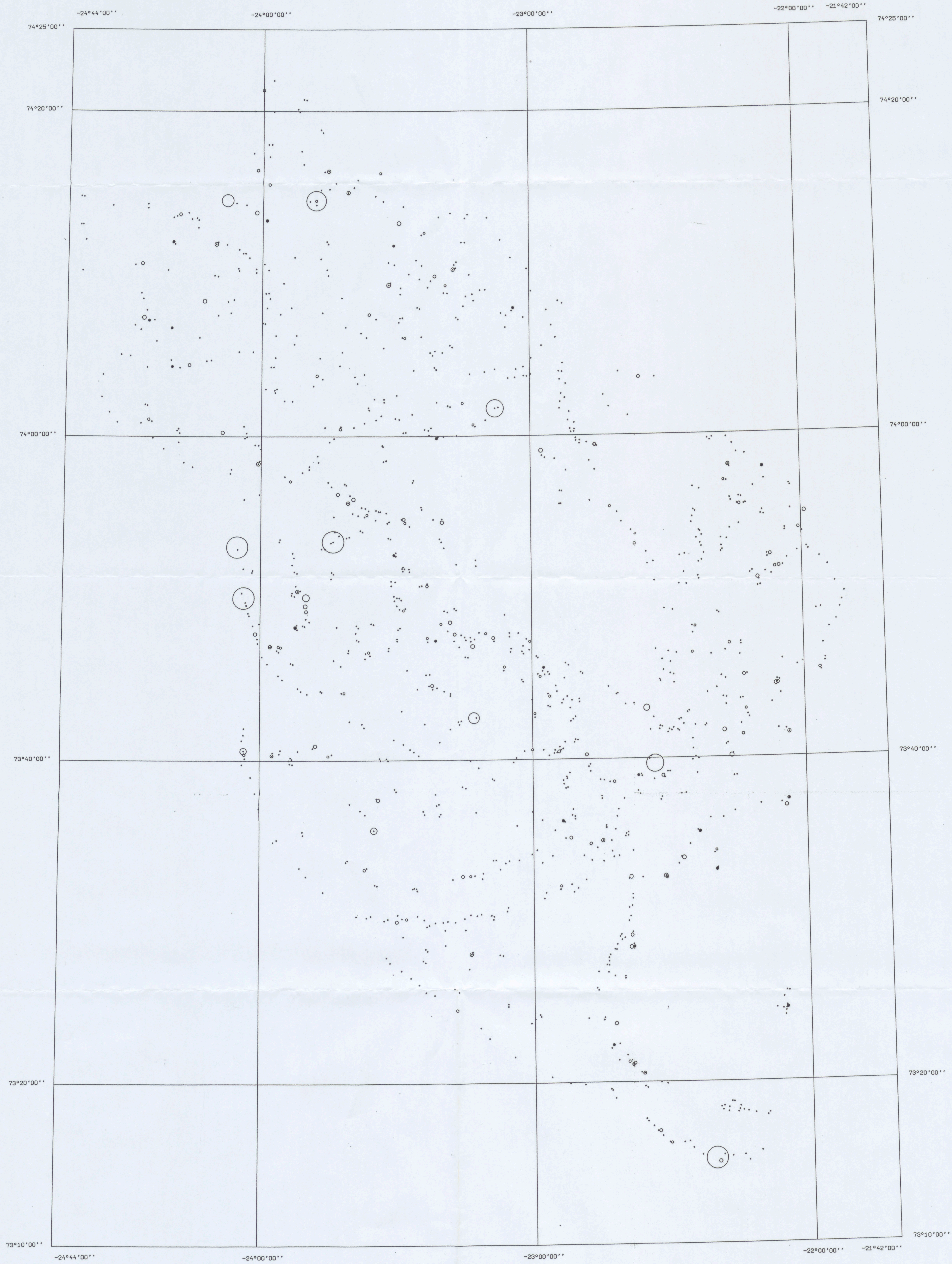
1:250 000

1:250 000 UTM-ZONE 27 (NAD83-NAD83)

GRØNLANDS GEOLOGISKE UNDERSØGELSE

MOSKUSOKSEFJORD

TOPOGRAPHIC BASE MAP COMPILED BY THE GEOLOGICAL SURVEY OF GREENLAND. AERIAL PHOTOGRAPHS AND GROUND CONTROL POINTS SUPPLIED BY KORT- OG MATRIKELSTYRELSEN. DANMARK (A.200/87).

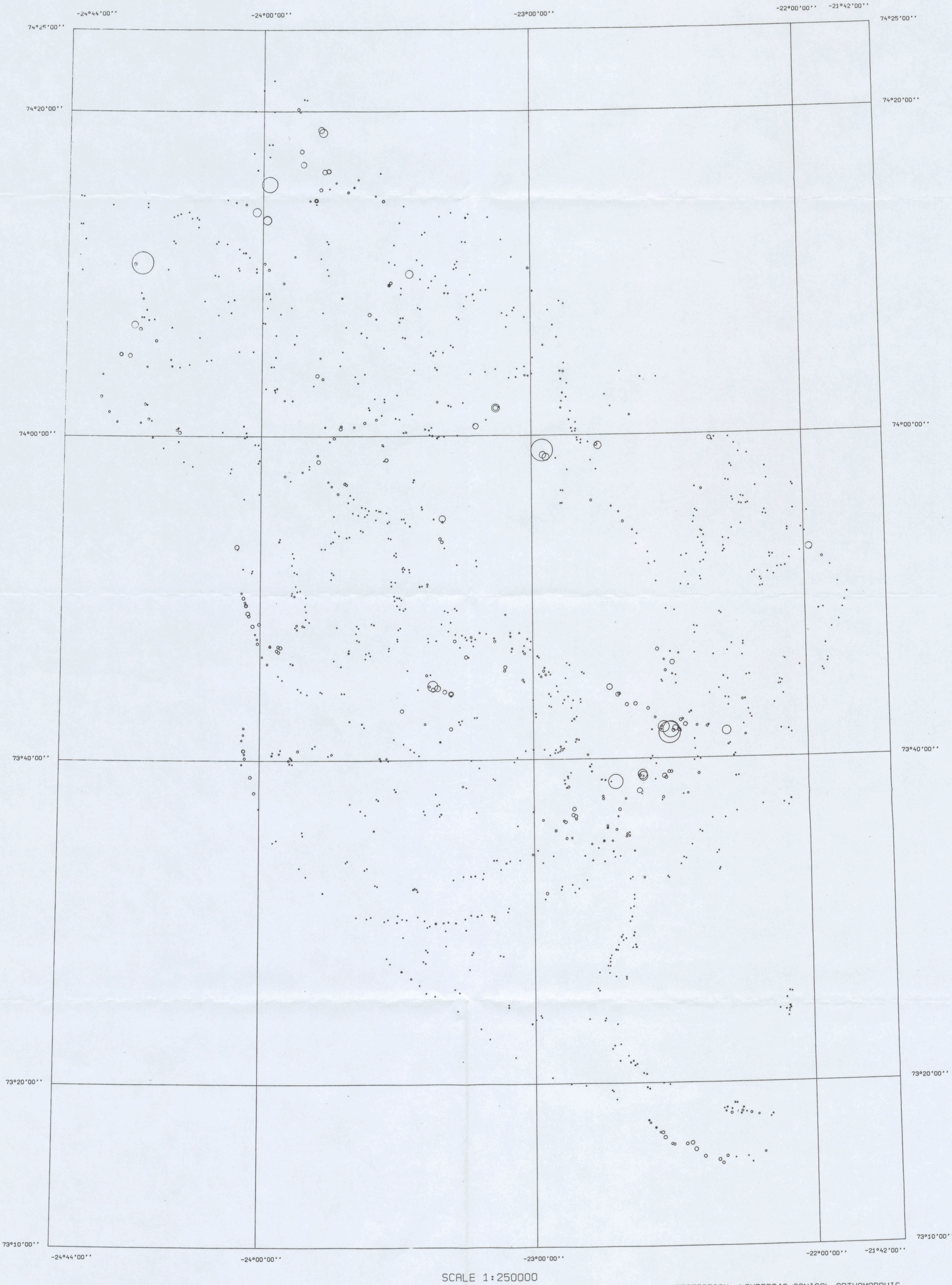


SCALE 1:250000

HUDSON LAND STREAM SEDIMENTS
GRAIN SIZE FRACTION <150 MICRON

ELEMENT	*UNIT*	*SC.FACT*	*MAX*	*MIN*
AU	PPB	0.01	0.5	0.02

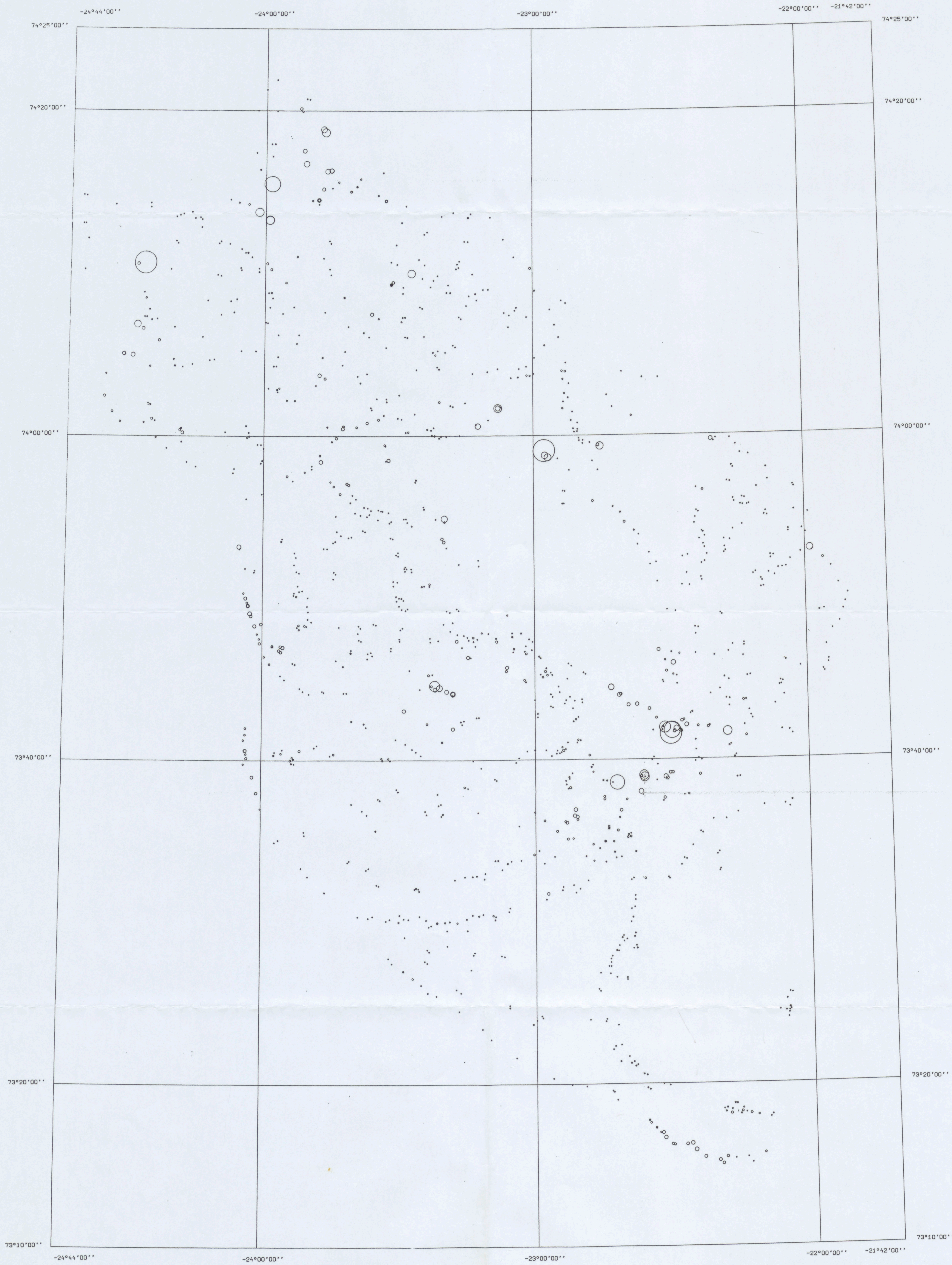
PROJECTION: LAMBERT'S CONICAL ORTHOMORPHIC.
ELLIPSOID: INTERNATIONAL. A = 6378388M. F = 1/297.
STANDARD PARALLEL: 73G 30' 00' N



HUDSON LAND STREAM SEDIMENTS
GRAIN SIZE FRACTION <150 MICRON

ELEMENT	UNIT	SC.FACT	MAX	MIN
AS	PPM	0.005	0.5	0.02

PROJECTION: LAMBERT'S CONICAL ORTHOMORPHIC.
ELLIPSOID: INTERNATIONAL. A = 6378388M. F = 1/297.
STANDARD PARALLEL: 73G 30' 00' N



SCALE 1:250000

HUDSON LAND STREAM SEDIMENTS
GRAIN SIZE FRACTION <150 MICRON

ELEMENT	*UNIT*	*SC.FACT*	*MAX*	*MIN*
AS	PPM	0.005	0.5	0.02

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