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STRUCTURES ASSOCIATED WITH EVAPORITE DIAPIRS ON ELLEF RINGNES ISLAND, NORTHEAST SVERDRUP BASIN, NUNAVUT

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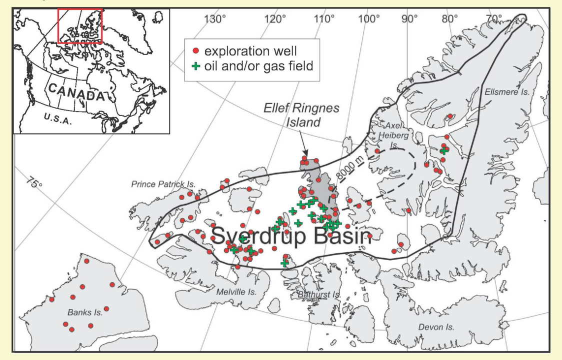
INTRODUCTION

Depositional history of the Sverdrup Basin began with accumulation of evaporites and carbonates in the Carboniferous and Permian, and was followed by siliciclastic deposition from Triassic to earliest Tertiary time. The maximum thickness of basin strata preserved is 13 km, and the succession is pierced by numerous evaporite diapirs. Petroleum exploration between 1969 and 1986 resulted in the discovery of 19 major petroleum fields. Ellef Ringnes Island is located near the centre of the Sverdrup Basin, at the northern extremity of the belt of discoveries.



Location of the Sverdrup Basin, the 190 exploration wells (red), discovered oil and gas fields (green), and Ellef Ringnes Island.

Objectives of new bedrock mapping on Ellef Ringnes Island are to: facilitate integration of surface and subsurface data by applying modern stratigraphic terminology, including new subdivisions of units; improve understanding of the evolution of evaporite diapirs by analysis of associated structures; and develop a more robust overall geological framework for integration of surface and subsurface well and seismic data. Seven weeks of fieldwork over the 2010 and 2011 field seasons is supplemented by analysis of oblique aerial photographs and satellite imagery to produce a preliminary new map of the island (in progress), and interpret structures. This poster presents an overview of recent work, with emphasis on structural styles.

STRATIGRAPHY

The oldest rocks on Ellef Ringnes Island are Carboniferous evaporite and minor carbonate of the Otto Fiord Formation. All occurences but one are within seven evaporite diapirs in the southern 2/3 of the island.

Jurassic rocks are confined to the northern third of the island. New work there includes application of terminology of Balkwill et al. (1977) and Embry (1984). Cretaceous clastic rocks underlie the southern 2/3 of the island.

The Lower Cretaceous Isachsen Formation is subdivided into its Paterson Island, Rondon, and Walker Island members by mapping the marine shale of the Rondon Member. A new local unit of the Isachsen Formation is a succession of volcanic and volcaniclastic strata in the Paterson Island Member. The overlying Christopher Formation is subdivided into the Invincible Point and Macdougall Point members. New work recognizes a widespread volcanogenic component to sandstone and carbonate at or near the top of the Invincible Point Member, including lapilli, glass shards, and bentonite(?). An isolated pile of coarse massive volcaniclastic rock at least 80 m thick that includes pillows and pillow fragments occurs near the top of the Macdougall Point Member at Cape Cairo. New work in the Lower and Upper Cretaceous Hassel Formation recognizes a locally mappable marine shale, and 2 isolated exposures of coarse volcaniclastic rock similar to that in the upper Christopher Formation. These occur near the base of the Hassel Formation at Cape Cairo and south of Hoodoo Dome. Distribution of the Upper Cretaceous Kanguk Formation and Eureka Sound Group is largely as mapped previously.

New work has recognized volcanic and volcaniclastic components in the Isachsen, Christopher, and Hassel formations. Most of the occurrences were previously mapped as intrusive rocks. They expand southwestward the region of known Cretaceous volcanic occurrences in the Queen Elizabeth Islands described by Embry and Osadetz (1988). Mafic intrusive rocks are widespread in the northern third of the island; sills are the most common mode of occurrence.

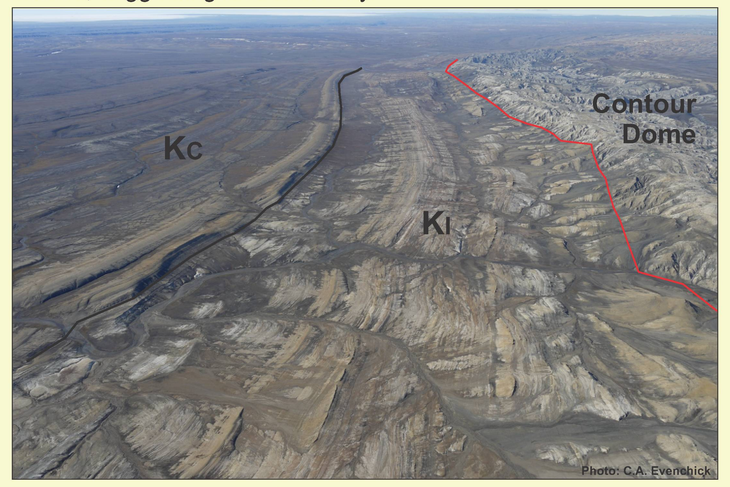
STRUCTURE

The distribution of map units on Ellef Ringnes Island is controlled at the largest scale by the general southward dip from the Sverdrup Rim at the northwest limit of the island, where Jurassic rocks are exposed, to the southeast end of the island, where latest Cretaceous strata dominate. Superimposed on this regional dip are large-scale northwest-trending open folds, commonly with wavelengths >5 km, and interlimb angles generally greater than 150°. Tilting associated with emplacement of evaporite diapirs resulted in the most significant local structural relief. Within 1 km of the flanks of the diapirs bedding increases in dip laterally from less than 20°, typical of most of the island, to steep, vertical, or overturned at the faulted boundaries of the evaporites.

Faults occur in 3 associations. One group has wide variation in strike, and is spatially associated with the evaporite diapirs. The second is an array of northeast-trending steep faults; these are the primary structures in the northern third of the island. They are spatially associated with less common northeast-trending small scale folds. The third, restricted to the vicinity of Reindeer Peninsula in the far northwest, comprises northeast and east-trending steep faults. Maps and photographs at right discuss all structures in greater detail.

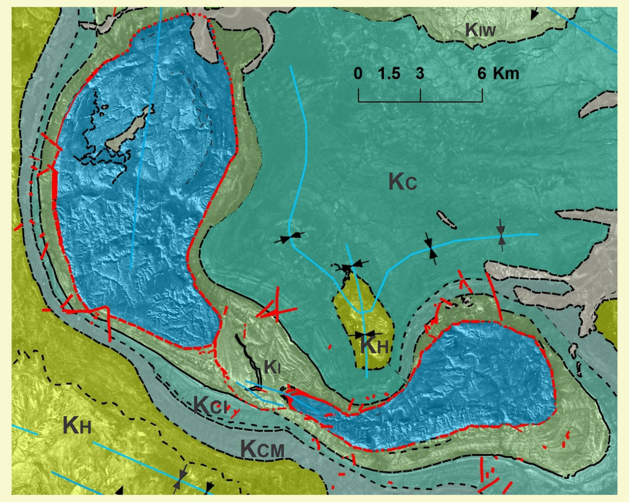
EVAPORITE DIAPIRS

Seven evaporite diapirs range from several hundred metres to several km across. The largest and best exposed are Dumbells, Contour, and Isachsen domes. Haakon, Malloch, and Helicopter domes are partially exposed at the edges of the island. In addition to gypsum and anhydrite, most diapirs include significant exposure of mafic intrusive rock and carbonate. The diapirs occupy the highest elevations on the island and are deeply incised, suggesting recent activity.

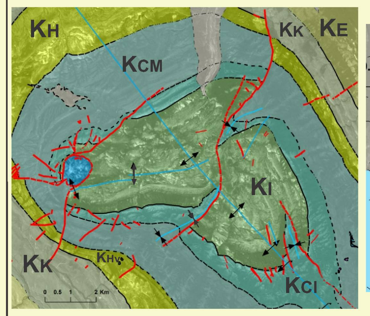


View west along the south flank of Contour Dome, showing its elevation relative to bounding strata, and the decrease in dip away from the dome.

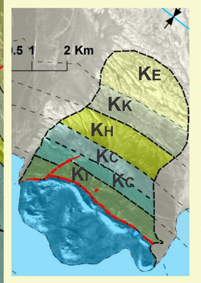
Dumbells and Contour domes



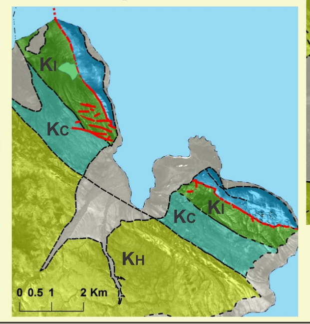
Hoodoo Dome



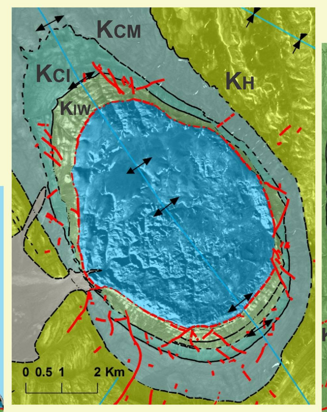
Malloch Dome



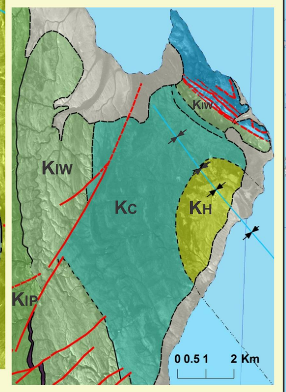
Helicopter Dome



Isachsen Dome



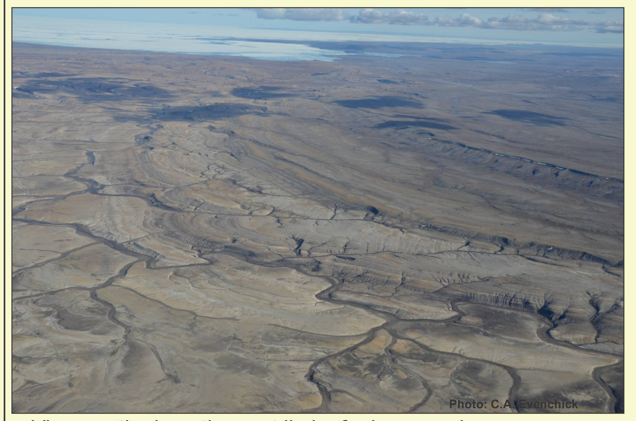
Haakon Dome



fault

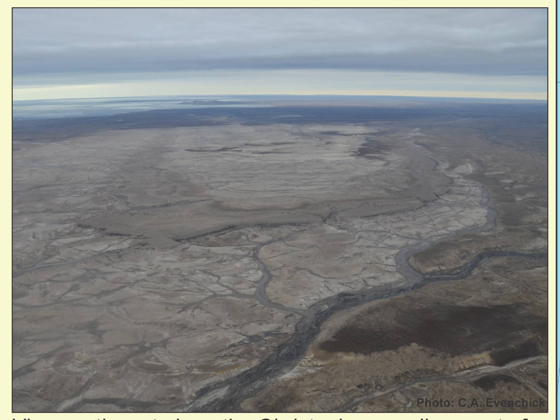
all maps are in progress

LARGE-SCALE FOLDS



View south along the east limb of a large-scale open syncline south of Haakon Dome; Isachsen Formation.

Large-scale folds trend northwest, are open folds or warps, and have wavelengths >5 km. Interference with tilted beds on the flanks of evaporite diapirs results in local deflections of trends. These folds affect all stratigraphic units and are assumed to have formed during Eurekan (Tertiary) deformation. Thrust faults are rare, and have minor displacement.



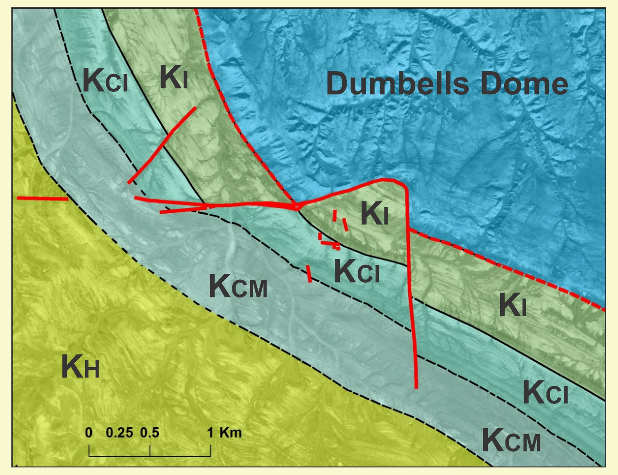
View northwest along the Christopher syncline west of Hoodoo Dome. Eureka Sound Formation.

EXTENSIONAL FAULTS MARGINAL TO EVAPORITE DIAPIRS

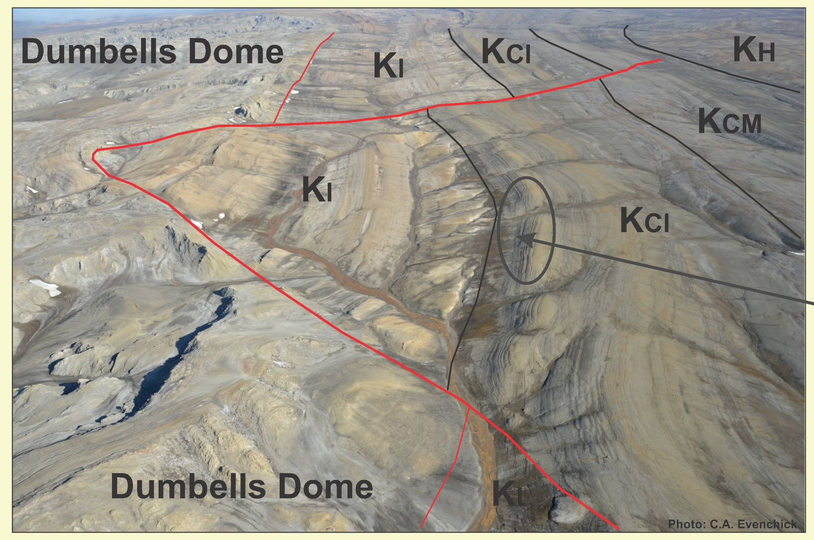
Steeply dipping faults offset Cretaceous strata bounding all evaporite diapirs on Ellef Ringnes Island. Some of these faults also affect the diapirs.

The faults exhibit *apparent* strike-slip offset, but collectively are most reasonably interpreted as extensional faults that formed during deposition of Cretaceous units. Tilting associated with diapiric movement of evaporite rotated the faults and their offset contacts to the current positions, presenting apparent strike-slip offsets of opposing senses. The faults are most common in the Isachsen and Christopher formations.

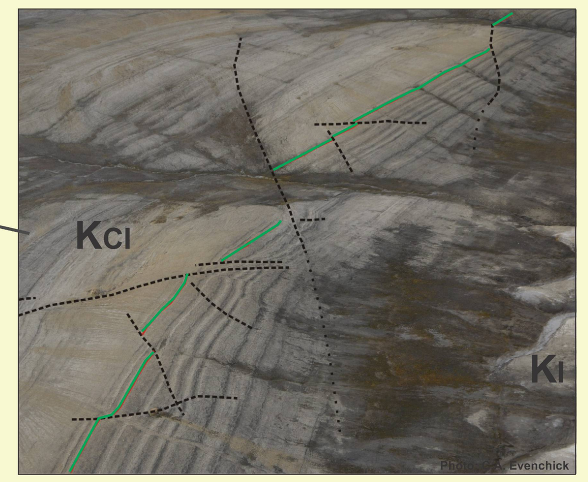
One example of this type of fault is on the flank of Dumbells Dome (right and below). 700 m of apparent offset of the Isachsen-Christopher contact represents 600 m of syn-Christopher dip-slip if the fault is extensional. The thickness of the upper Christopher Fm within the graben compared to its thickness NW and SE of the main faults indicate that most of this displacement occurred during deposition of the upper, Macdougall Point, member of the Christopher Formation.



Map of the southwest boundary of Dumbells Dome, showing the late-Christopher extensional faults (red), and their affect on the thickness of the Christopher Formation.



View southeast along the southwest boundary of Dumbells Dome, and the faults cutting the boundary and overlying units, as shown on the map above right.



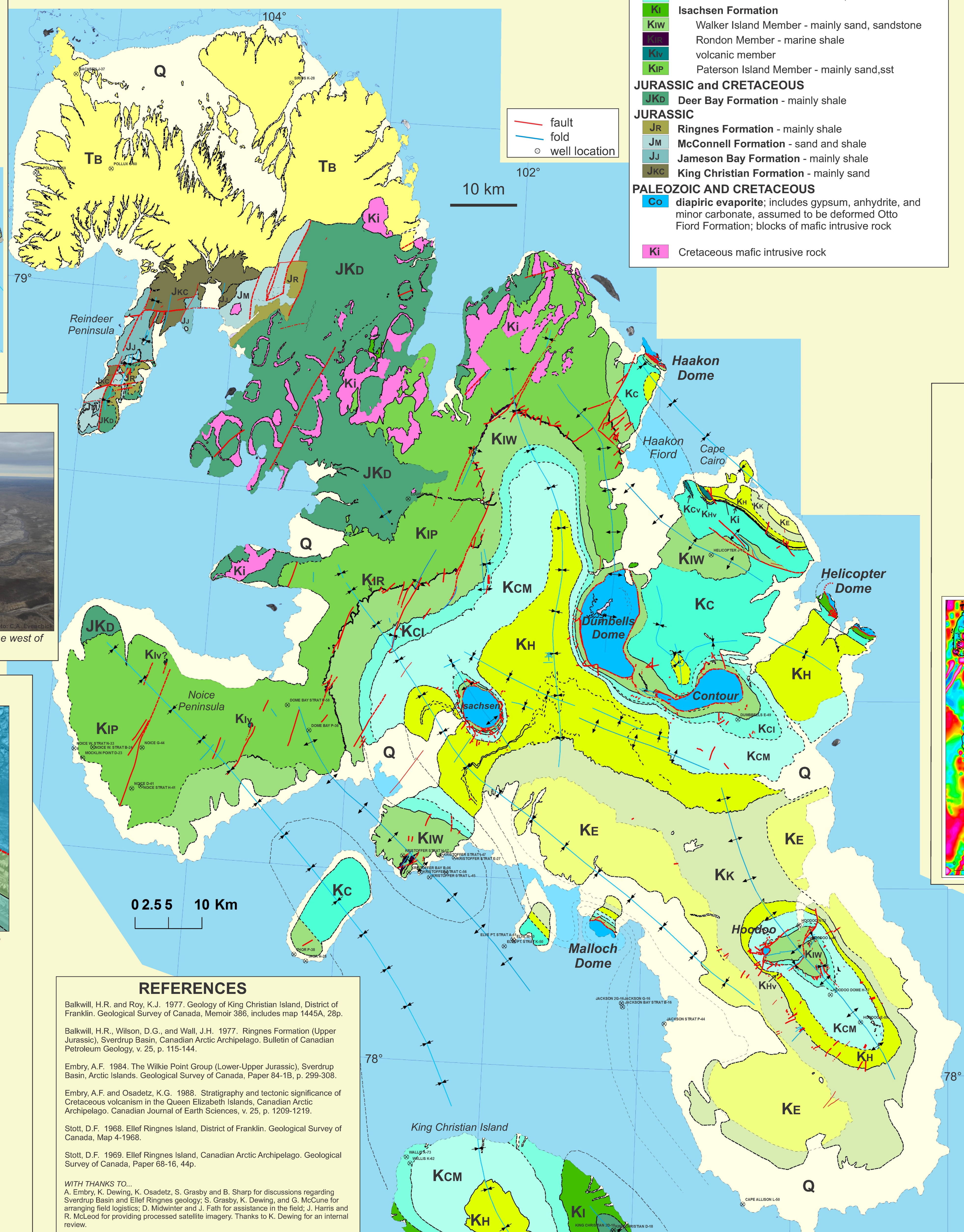
View northwest to some the smaller scale faults associated with the graben at the SW margin of Dumbells Dome.

NEW BEDROCK MAP OF ELLEF RINGNES ISLAND

Compilation of a new map of the island is in progress. The map below is revised from Stott (1968). Geology of King Christian Island is from Balkwill and Roy (1977).

Primary differences from Stott (1968) are application of current stratigraphic terminology, including subdivision of the Isachsen and Christopher formations into their constituent members. Other revisions include refinement and considerable increase in detail of structures, and contacts of intrusive units. Many of these revisions are facilitated by improved base data, and by use of SPOT satellite imagery, and locally Quickbird and Worldview imagery.

Future work on the map will focus on refining contacts in the northern third of the island and around the diapirs, delineating intrusive rocks in the diapirs, and completing analysis of faults and folds.



TERTIARY
- TB — **Beaufort Formation** - unconsolidated sand, gravel

CRETACEOUS
- KE — **Eureka Sound Group** - mainly sand, sandstone
- KK — **Kanguk Formation** - mainly shale
- KH — **Hassel Formation** - mainly sand, sandstone
- KHv — volcanic member
- KC — **Christopher Formation**
- KCv — volcanic member
- KCM — Macdougall Point Member - mainly shale
- KCI — Invincible Point Member - shale, minor sandstone
- KI — **Isachsen Formation**
- KIW — Walker Island Member - mainly sand, sandstone
- KIR — Rondon Member - marine shale
- KIv — volcanic member
- KIP — Paterson Island Member - mainly sand,sst

JURASSIC and CRETACEOUS
- JKD — **Deer Bay Formation** - mainly shale

JURASSIC
- JR — **Ringnes Formation** - mainly shale
- JM — **McConnell Formation** - sand and shale
- JJ — **Jameson Bay Formation** - mainly shale
- JKC — **King Christian Formation** - mainly sand

PALEOZOIC AND CRETACEOUS
- Co — **diapiric evaporite**; includes gypsum, anhydrite, and minor carbonate, assumed to be deformed Otto Fiord Formation; blocks of mafic intrusive rock

- Ki — Cretaceous mafic intrusive rock

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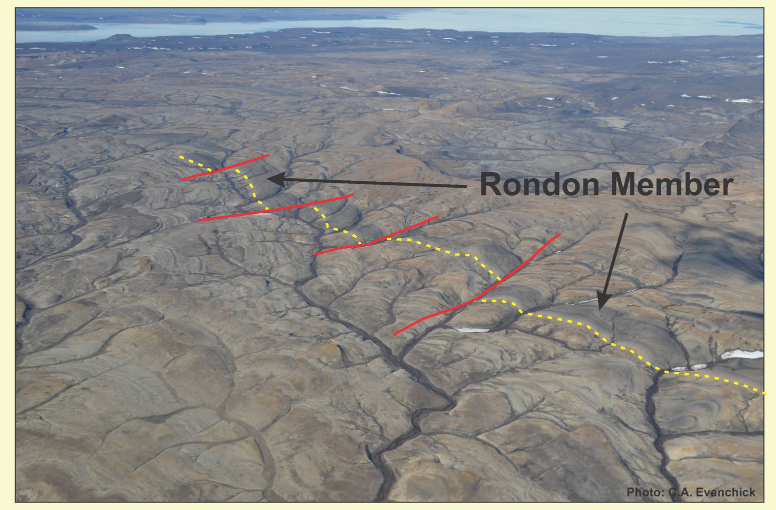
NORTHEAST-TRENDING FAULTS

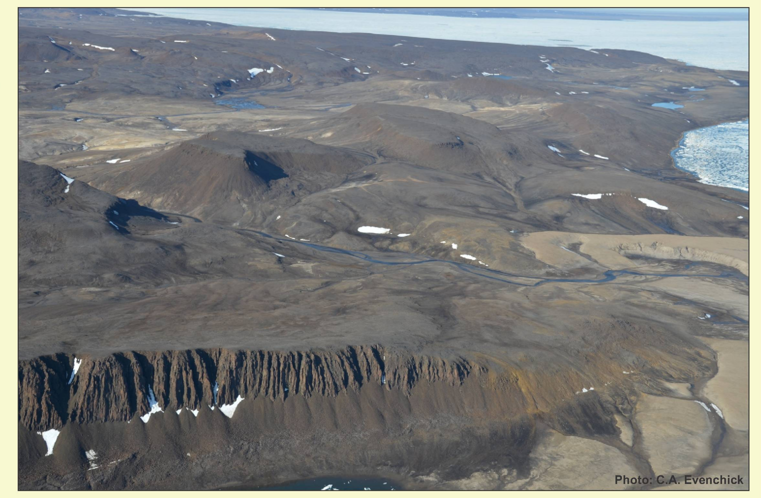
Steep northeast-trending faults are common in the northern half of the island. In many cases their apparent offset, typically less than 1 km, can be determined from local markers. Map relationships locally permit interpretation of sense of displacement; these cases are commonly dip-slip. Whether the faults accomodated crustal extension or contraction is difficult to determine because the direction of dip is obscured. A small proportion have been interpreted as normal faults, and fewer as reverse. Future work will focus on analysis of this suite of faults. Two relationships suggest that many of the faults may be extensional:
1) they are parallel with prominent aeromagnetic anomalies (see diagram below) which are interpreted to reflect dykes in the subsurface. The dykes are assumed to have fed the widespread sills in the northern third of the island that are spatially associated with the the region of NE-trending aeromagnetic anomalies.
2) the few occurences of volcanic / volcaniclastic rocks are spatially associated with faults of this trend.

View northeast along a steep fault and zone of altered Isachsen sandstone (foreground), to the pile of volcanic and volcaniclastic rocks in the lower Isachsen Formation (background). This is one example of volcanogenic strata associated with steep faults. Bedding in the altered foreground outcrop is subhorizontal; the steep surfaces are faults and fractures.

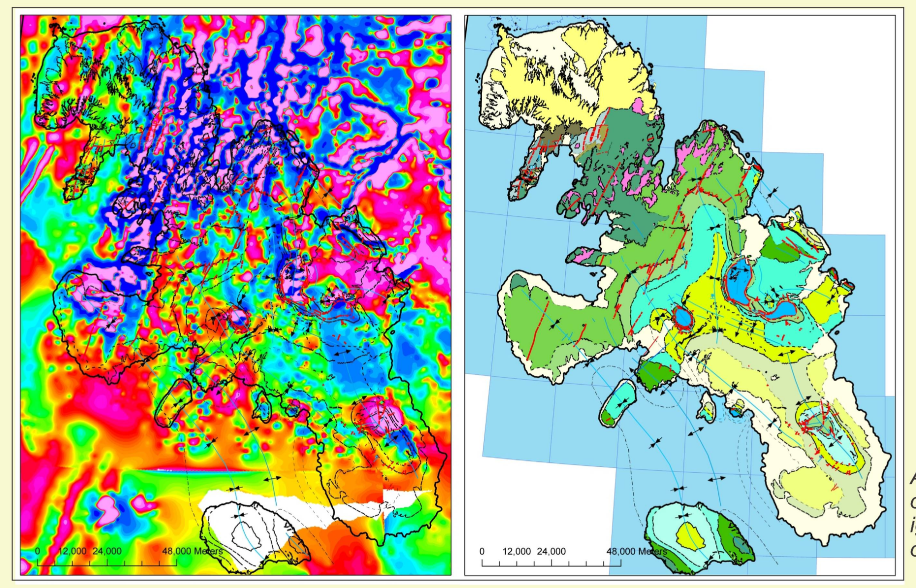


Faults west of Haakon Fiord show different apparent senses of offset of the Rondon Member(above, below); this is one relationship that suggests dip-slip rather than strike-slip offset. The stratigraphic top of the Rondon Mbr in the photo is highlighted with a yellow dotted line; faults are red.

Coarse volcanic strata in the upper Christopher Formation, Cape Cairo. Large blocks are pillow fragments.



Sills in the northern third of the island (e.g. foreground bluffs) are spatially associated with a prominent northeast trend of aeromagnetic anomalies. Northeast-trending faults are also common in this region. NW of Haakon Dome.

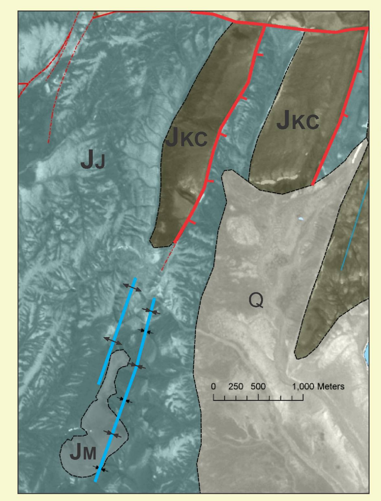


Aeromagnetic anomaly map (left) showing the coincidence of a linear belt of anomalies with the region underlain by igneous rocks in the northern third of the island, and their orientation relative to the suite of northeast-trending faults.

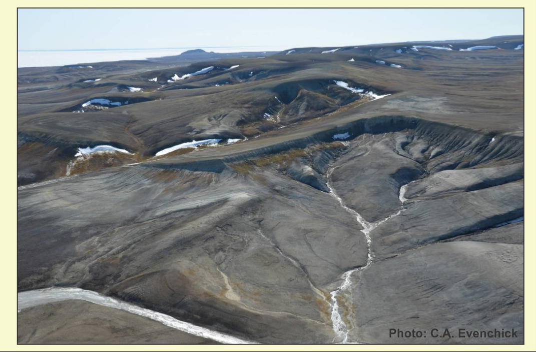
FOLDS ASSOCIATED WITH NORTHEAST-TRENDING FAULTS

The majority of folds less than 1 km in wavelength trend northeast and are spatially associated with steep faults. In some cases the folds are parallel with the faults, and in some cases the folds are along trend of the fault, accomodating the same overall displacement.

View southwest along folds associated with a northeast-trending fault, west Noice Peninsula. Farther northwest this fold is spatially associated with outcrops of igneous rocks. Isachsen Formation.



Map at left shows a normal fault dropping Jameson Bay Formation (JJ) down against King Christian formation (JKC); fault dip and slickenlines observed in outcrop. Southwest of the fault the same displacement is accomodated by folds. The photo below, viewed to the southwest, is to those folds. Reindeer Peninsula.



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