23. STRUCTURAL GEOLOGY OF SOMERSET ISLAND AND BOOTHIA PENINSULA, DISTRICT OF FRANKLIN

Project 740030

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Introduction

The geology of Somerset Island and Boothia Peninsula (Fig. 23.1) is dominated by the Boothia Uplift (Kerr and Christie, 1965), a north-trending positive basement controlled tectonic feature. The Boothia Uplift is redefined by Kerr (in press). In the report-area, it includes a core of crystalline basement rocks called the Boothia Horst, and the overlying and adjacent sedimentary superstructure of folded Paleozoic rocks called the Cornwallis Fold Belt. The horst is part of the Churchill Province of the Canadian Shield. Positive and negative movements of the horst produced the structures of the fold belt. Extensive normal faulting that affected the area after activity of the uplift is related to continental drift.

A prime objective of the present study is to locate faults on Somerset Island and Boothia Peninsula to assist in choosing a route for a proposed natural gas pipeline. The work on the crystalline rocks was done by de Vries, and on the sedimentary rocks by Kerr. The present paper reports the result of 1976 fieldwork, and expands upon an earlier paper (Kerr and de Vries, 1976).

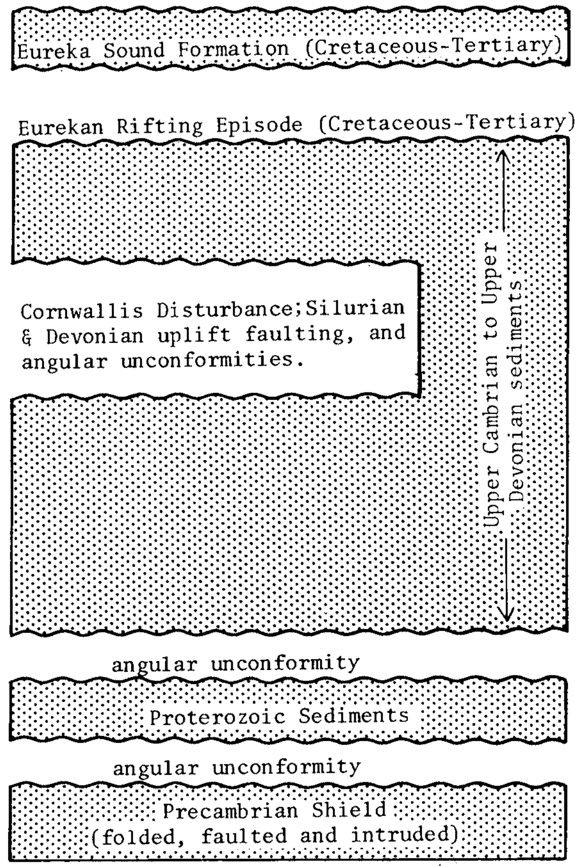

Figure 23.1. The main divisions in the stratigraphic column and the tectonic events of Somerset Island and Boothia Peninsula.

The Crystalline Precambrian Shield

The entire area of the Canadian Shield exposed on Somerset Island has now been mapped, with study being concentrated in the southern part where exposure is good. In southern Somerset Island, the various phases of folding can be distinguished clearly by mapping relatively well exposed calcsilicate and metabasite markers. The entire Shield area of Somerset Island was affected by late, regionally pervasive north-south trending folds. In the south these folds are relatively open, and permit the recognition of earlier fold phases, as well as the interference patterns resulting from late phase overprinting of earlier folds. By contrast, in northern Somerset Island the late folding structures are tight, and tend to obscure evidence of earlier structures.

The various fold phases have a slightly different designation in this report than that used in an earlier report (Kerr and de Vries, 1976). In this report, F_1 refers to the rare, oldest set of tight or isoclinal folds. The set referred to as F_2 is newly recognized; these folds are locally developed, open folds that trend approximately east-west. In this report, F_3 refers to the regionally pervasive structures that were termed F_2 earlier (Kerr and de Vries (1976). The elongate domal and basinal structures in the Bellot Strait – Fitz Roy Inlet region are the result of interference between east-west trending F_2 structures and north-south trending F_3 folds.

Mesoscopic features in isolated outcrops attest to the complex sedimentary, structural, metamorphic and plutonic history of the crystalline rocks now forming the core of the Boothia Uplift. The combined intensity of F_1 and F_3 deformational events, however, has tended to transpose initial angular discordances between rock units by extensive flowage parallel to the axial surfaces of the structures.

Two lithological units in the Shield that are of sedimentary origin and can be traced for considerable distances around megascopic structures, are the calcsilicates and marbles, and the garnet sillimanite gneisses. These units have been thinned tectonically so that they

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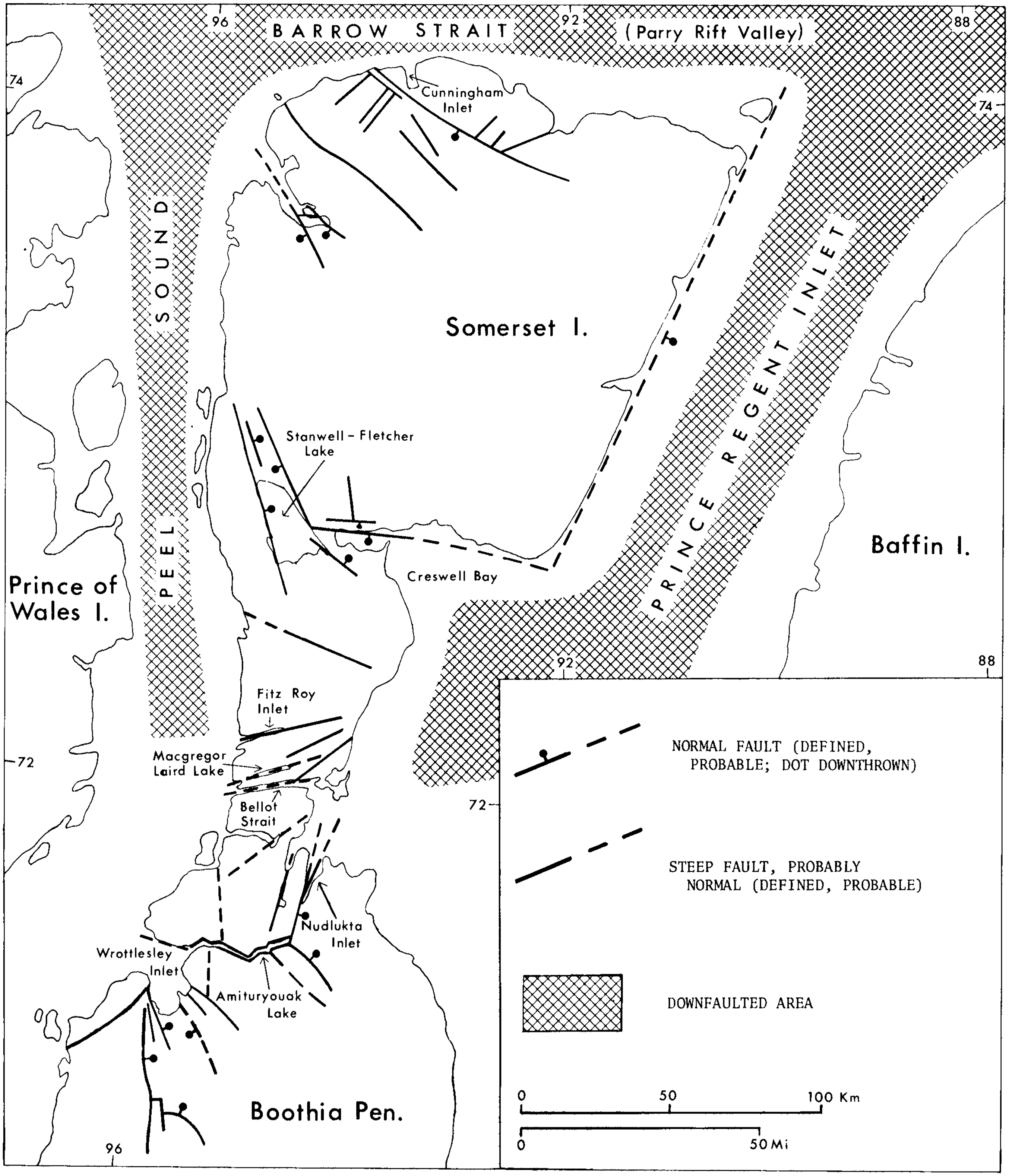

Figure 23. 2. Structures formed on Somerset Island and Boothia Peninsula during the Eurekan Rifting Episode.

commonly disappear altogether along strike. They, nevertheless, have been traced over remarkably long distances; in places they are not thicker than 20 cm. Calcsilicate bands now have been mapped over the entire length of the exposed Shield of Somerset Island.

Four lithological units probably can be regarded as pre-F_3 intrusives into the layered gneisses, although discordant relationships can rarely be demonstrated in the field.

1) A thick, poorly foliated, monotonous, brown-weathering quartz-feldspar gneiss, in which biotite and hornblende sometimes occur, is present at the coast west of Macgregor Laird Lake, and along the limbs of F_3 structures farther east. The relatively abrupt weakening or disappearance of the quartz foliation in these rocks near the contact with well foliated gneisses, and the monotonous character of the mineralogy of this unit suggest that it may have originated as an acid intrusive. The unit can be traced around several F_3 synforms and antiforms, but appears to be concordant with the surrounding foliated gneisses.

2) Numerous metabasites, that range from 50-cm-thick agmatitic bands to 100-m-thick metabasite sheets, are present over the entire map-area. They commonly display a pronounced mineralogical change from a coarse hornblendite core to a finer grained pyroxene and plagioclase-rich border zone. At two localities the metabasites have discordant relationships with the surrounding gneisses, suggesting that the metabasites originated as intrusive sheets.

At least some of the metabasites were emplaced prior to the F_1 event since, at one locality, a thick metabasite occupies the core of an F_1 antiform refolded by an F_3 synform.

3) Coarse pegmatitic bodies, both discordant and concordant, are present throughout the entire map-area, although they are not abundant.

4) Thin, conformable lenses of serpentinized ultramafic rocks have been found in the Bellot Strait – Fitz Roy Inlet region. A sheet-like network of serpentine surrounding remnants of coarse orthopyroxene is oriented approximately parallel to S_3 surfaces, suggesting that the ultramafic unit was emplaced before F_3 deformation ceased.

Migmatization has affected all pre-F_3 rock units with the possible exception of the ultramafics. The amount of leucosome varies greatly with the rock type. Garnet-sillimanite gneisses in some cases, for example, contain up to 60 per cent quartzofeldspathic leucosome that is distributed as thin, irregular layers in the gneiss. Thin metabasites commonly display agmatitic textures, while the leucosome in the thicker metabasites commonly is concentrated in discrete veins.

Evidence from isolated outcrops suggests that probably more than one episode of migmatization affected the rocks since F_1 deformation took place. Early layered rock units, including calcsilicates and sillimanite-garnet gneisses are involved in tight to isoclinal F_1 folds. These mesocopic structures are cut discordantly by fine- to medium-grained quartzofeldspathic mobilizates, which also occur as concordant layers parallel to the overall lithological layering. This unit, in turn, is cut by a set of coarse grained pegmatitic sills and dykes that are oriented approximately parallel to S_3 surfaces.

The Cape Granite granite is a mesozonal pluton (Kerr and de Vries, 1976) that occurs at Cape Granite on northwestern Somerset Island and postdates F_3 deformation. Late Proterozoic diabase dykes, sills and plugs, that occur over the entire exposed Shield, are the youngest intrusive events to affect the Shield of Somerset Island.

Folds in the Crystalline Shield

All three phases of folding recognized to date, F_1, F_2, and F_3, are represented by large, macroscopic structures in the southern part of Somerset Island. The F_3 structures, however, are the most important regionally, and determine the predominantly north-south trending structural grain of the Precambrian Shield of Somerset Island.

The F_1 folds are tight to isoclinal structures that probably occur throughout Somerset Island, but can be positively identified only in hinge regions of broad, open F_3 folds.

A well-developed quartz foliation, defined by platy quartz, is present in all quartz-rich rocks. Since the quartz foliation is oriented parallel to axial surfaces of F_3 folds, and occasionally can be seen to cut across limbs of F_1 folds, it was thought to have been formed during F_3 deformation (Brown *et al.*, 1969; Kerr and de Vries, 1967). In some hinge areas of open F_3 folds, however, two sets of quartz foliation are present, one parallel to the axial plane of F_3 folds, the other parallel to gently dipping axial surfaces of F_1 isoclines. It seems that some of the platy quartz that developed during F_1 survived reorientation during penetrative F_3 deformation.

A prominent quartz lineation, at the intersection of the platy quartz foliation and the lithological layering, is present at many localities on the Shield, and often can be demonstrated to be parallel to F_3 fold hinges. In the area west of Stanwell-Fletcher Lake, the quartz lineations consistently plunge gently southward, while F_3 hinges plunge northward, again suggesting that some of the quartz foliation formed prior to F_3 deformation.

The complex fold pattern that was produced by interference between F_1 and F_3 perhaps is exemplified best by a large-scale, doubly plunging, "banana-shaped" structure north of Macgregor Laird Lake. The F_1 axial plane can be traced for a distance of 3 km around several F_3 hinges. The F_1 axial plane is parallel approximately to the lithological contacts and the tight F_1 hinges can be recognized only by the presence of calcsilicate markers. The F_1 fold has been refolded by a number of north-trending F_3 folds with steep axial planes and variably plunging axes.

The original orientation of F_1 structures is unknown, and the attitude of only a few F_1 hinges could be determined. Field evidence, however, seems to suggest that F_1 folds are present over an extensive area, and tight F_1 folds perhaps may have dominated the structure of the map-area before the advent of F_3 deformation.

The F_2 structures are east-west trending, open folds with steep axial planes that can be recognized by their characteristic domal or basinal interference pattern with F_3 folds. No mesoscopic folds are associated with F_2 structures. The shape of the domes and basins is determined largely by the tightness of F_3 folds. Two oval-shaped basins outcrop west of Macgregor Laird Lake. A good example of an elongated dome is the structure north of Fitz Roy Inlet along Peel Sound, while a nearly circular dome, outlined by a calcsilicate band, occurs 40 km to the north. The F_2 structures, probably originated as gentle, east-west oriented warps in F_1 isoclines.

The F_3 structures, which are dominant and trend north-south, display almost the entire spectrum of fold styles from open concentric to tight similar folds. Open F_3 folds are more abundant in the southern part of Somerset Island than farther north.

Axial planes of F_3 folds invariably are steep to vertical and, in mesoscopic folds, platy quartz commonly marks the axial trace. The profiles of many major F_3 folds show that parasitic folds generally are restricted to a narrow hinge zone and are absent from the limbs.

Fold axes of F_3 folds generally plunge between 10 and 30 degrees northward, but plunge reversals occur in the domal and basinal F_2/F_3 interference structures. An extremely variable pattern of F_3 plunges was observed in the large-scale "banana-shaped" F_1/F_3 interference structure north of Macgregor Laird Lake referred to previously. This pattern is attributed to a combination of two factors: the difference in attitude of beds separated by the F_1 axial plane at the onset of F_3 folding; and the ductile behavior of marbles and calcsilicates in the cores of folds.

Faults in the Crystalline Shield

Two prominant topographic lineaments in the southern part of Somerset Island are east-northeast trending faults with an apparent right-lateral strike-slip displacement in the crystalline rocks. At Macgregor Laird Lake, correlation of lithological markers and traces of axial planes of folds across the lake indicate right-lateral displacement within the Shield. The displacement decreases eastward, being 2.5 km near the west end, 2.2 km in the middle, and 0.3 km east of the lake. The fault in Fitz Roy Inlet had approximately 2 km of right-lateral displacement within the Shield.

In both of the strike-slip faults mentioned above, nearly all of the displacement cited occurred prior to the Paleozoic column, whose base is Upper Cambrian (Miall and Kerr, this publ., rep. 22). On their east ends, however, the two faults offset the Paleozoic rocks with a small amount of mainly vertical displacement. This vertical displacement is considered to be a rejuvenation in Cretaceous or Tertiary time (*see* below).

Bellot Strait appears to occupy a shear zone parallel to its trend, that developed, presumably, in Precambrian time. No estimate of the sense or amount of displacement can be given because markers were not traced to the south. A minimum age for the Precambrian faulting along the three east-northeast trending structures in the Shield of southern Somerset Island described above would be set by the shearing and veining of a diabase plug near the eastern entrance to Bellot Strait.

Sedimentary Cover Rocks

The sedimentary cover rocks of Somerset Island and Boothia Peninsula lie unconformably upon the crystalline Shield and range in age from Late Cambrian to Late Cretaceous. They have been summarized by Reinson *et al.* (1976), Kerr (in press), and by Miall and Kerr (this publ., rep. 22).

The main divisions in the stratigraphic column and tectonic events that occurred on Somerset Island and Boothia Peninsula are shown in Figure 23.1. The times in which rock was being deposited are shown by pattern, and the times of tectonic disturbance are shown by the intervening blank spaces.

All structures that now exist in the sedimentary cover rocks of Somerset Island and Boothia Peninsula were controlled in a large way by the prominent gneissic trends in the underlying Precambrian crystalline basement. Nearly all faults that cut the sedimentary cover rocks follow older faults in the Shield that were reactivated.

Faults of the Cornwallis Disturbance

The Cornwallis Disturbance of Early Silurian to Late Devonian time affected much of Boothia Peninsula, and western Somerset Island. The structures that formed during that disturbance are described by Kerr (in press). In this area, they are dominantly steep to vertical faults and flexures, mainly north-trending. The forces causing that disturbance originated in or beneath the crystalline basement and extended upward into the sedimentary cover rocks. Between the Cornwallis Disturbance and the Eurekan Rifting Episode, Somerset Island and Boothia Peninsula apparently were not deformed structurally (Kerr, in press).

Faults of the Eurekan Rifting Episode

The Eurekan Rifting Episode is a tectonic event defined by Kerr (in press), in which the central Canadian Arctic was subjected to extension and major block faulting. Rift valleys and their branches were down dropped to form linear marine channels. A most striking downfaulted feature is Parry Submarine Rift Valley (Kerr, 1967, in press), which trends east-west and lies just north of Somerset Island (Fig. 23.2). In the central Canadian Arctic, the Eurekan Rifting Episode began in Late Cretaceous (Maestrichtian) time. There probably was additional faulting within Tertiary time, and this may continue to the present.

All faults that are shown on the map of Somerset Island and Boothia Peninsula (Fig. 23.2) are considered to have been active during the Eurekan Rifting Episode.

Older faults that were not reactivated during the episode are not shown. The Eurekan Rifting Episode preceded and coincided with deposition of the Eureka Sound Formation. Many of the faults of the Eurekan Rifting Episode (Figure 23.2) displace the Cretaceous Eureka Sound Formation. This includes the main fault south of Cunningham Inlet, where the Eureka Sound Formation was reported by Hopkins (1971), the graben at Stanwell-Fletcher Lake (Dineley and Rust, 1968), the short east-trending fault north of Creswell Bay (Dixon *et al.*, 1973), and a major fault at Wrottlesley Inlet. Other faults displace the Shield and the Paleozoic column only, but are attributed to the episode because of their configuration, extending into the present day marine channels. Nearly all faults of the Eurekan Rifting Episode appear to have rejuvenated older structures, or at least have been guided by the older structures in the Shield and Paleozoic cover.

Several major faults follow coastlines, with the coastal side downdropped relatively. The east-west fault bordering Creswell Bay is well documented on the west. It had vertical displacement only, with the south side down. It has been traced as far east as 93°40'W, but probably continues eastward. This fault may connect with another long, straight fault that trends along the east coast of Somerset Island. That eastern coastline, which probably is the straightest coastline in the Canadian Arctic Islands, is presumed to be faulted, mainly because of its straightness.

The Eureka South Formation is downfaulted against the crystalline shield on the west side of Wrottlesley Inlet on western Boothia Peninsula (Fig. 23.2). South of the inlet is a large low-lying valley, that is presumed to be large graben. This graben appears to connect with a large downfaulted area in Peel Sound.

The faults at Nudlukta Inlet cut Paleozoic rocks and appear to have been active during the Cornwallis Disturbance. Their configuration, extending northward to a channel, suggests reactivation in the Eurekan Episode. Amituryouak Lake contains downfaulted Paleozoic rocks at one location. It appears to have connected faults on either side of Boothia Peninsula during the Eurekan Rifting Episode. The main northwest-trending faults of northern Somerset Island have displacements that increase toward the north. They are considered to be southward projections from Parry Submarine Rift Valley (Kerr, in press).

The Eurekan Rifting Episode resulted from continental drift. The faults of that episode are westward extensions into the central Canadian Arctic from older and more substantial spreading centres farther east, Baffin Bay and Labrador Sea (Kerr, 1967). The stress configuration that produced the Eurekan Rifting Episode, that is the tendency for rotation apart of continental blocks, may still exist today. Thus, the faults of the Eurekan Rifting Episode (Fig. 23.2) are potential modern dry fault zones. These faults should be considered in pipeline or other construction projects on Somerset Island and Boothia Peninsula.

There is a concentration of earthquake epicentres in the area of Barrow Strait, with a more diffuse trend through Somerset Island, and down Boothia Peninsula (Basham *et al.*, in press). According to D.A. Forsyth (pers. comm., 1976), well over 90 per cent of the earthquakes north of latitude 60 degrees in Canada are of magnitude <5, and this may indicate that stresses are not large enough to effectively "creak" existing structures. We concur and suggest that current seismicity, which appears to coincide with the regions deformed during the Eurekan Rifting Episode, may be very mildly augmenting the deformation of the Eurekan episode.

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