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An investigation of faults in sediments in Hvalfjörður, and some critical comments

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AN INVESTIGATION OF FAULTS IN SEDIMENTS IN HVALFJÖRÐUR, AND SOME CRITICAL COMMENTS

1. INTRODUCTION

By request of Dr. Jón Hálfdánarson, *Spölur h.f.*, we have undertaken a brief investigation of the multi-channel seismic reflection data acquired in 1993 in the Hvalfjörður, for the purpose of checking if faulting could be detected in the sediments below the bottom of the fjord. As the sediments are quite young, Recent or Late Pleistocene, any faulting in the sediments overlying suspected zones of weakness in the basaltic lava basement (low-velocity zones) could indicate recent tectonic movements.

A systematic search was made in all locations where low seismic velocity (<4.0 km/s) in the basement was indicated in the seismic refraction profiling made by Orkustofnun in 1991, and Geoteam in 1993.

2. RESULTS

A total of 59 locations in the seismic sections were investigated, overlying basement low-velocity zones. It should be noted that the resolutions of the air-gun data within the sediments will not likely allow the detection of a fault displacement which less than 1-2 meters. The following conclusions were drawn:

1. No certain fault-escarpments or steps were detected in the sea-bed, but a few doubtful instances were encountered. If a detailed definition of steps in sea-bed is required, a reinterpretation of the echo-sounding and boomer profiling data must be made.

2. The sediments are inhomogeneous, and unbroken parallel reflection patterns are not often encountered over long distances. This make it practically impossible for most instances to decide on the possibility of fault movements, and this certainly applies to 29 instances of the 59 investigated. In 27 instances unbroken continuous reflectors were seen over low-velocity zones. In one instance a clear step was seen, and two other cases are possible. These three latter observations are high up in the sedimentary layer where it is quite thick, over irregular basement topography. Such steps in the sediments don't have to be related to basement faulting; faulting or slumping within the sediments and irregular deposition are also possible causes.

3. It is observed that irregularities in the basement topography, as defined by the seismic reflection data, frequently coincide with low-velocity zones, as indicated by the interpreted refraction sections. In the locations of the lowest velocities (<3,0 km/s in the sections by Geoteam and <3,5 km/s in the sections by Orkustofnun), basement steps or depressions are encountered, almost without exception. Two possible explanations apply. On one hand, fault-zones can be the cause of both low-velocity and excessive local erosion. On the other hand, basement topography can cause **false** indications of low-velocity zones, due to the limitations of the interpretation methods employed.

In conclusion, no definite indications of faulting in the sedimentary layer have been observed. It can also be stated that due to the irregular layering and structure of the sediments, such

indications would probably not be detected in most instances, even if they exist. It is also evident that the resolution of the seismic signal is a limitation. On the basis of these observations, it is our opinion that further investigations in this field are not likely to lead to firm conclusions.

On the map by Geoteam (map 33165-2), a number of "faults extending to seabed" are indicated by dots. These suspected faults were interpreted on the boomer single-channel data by the Geoteam representative, Dr. Duncan Tamset. In our opinion the majority of these instances were due to minor faults in the data recording, and therefore not real. These data have not be reconsidered, and we will not claim that all of these possible fault indications can be explained away in this way.

3. ON THE INTERPRETATION OF FAULT LINEATIONS BY GEOTEAM

In this re-interpretation of the 1933 data we found a discrepancy between the depth-to-basement map presented by Geoteam (1993 report no. 33165.01, maps 33165-2 and -3, Vol. 1) and the corresponding map made by Orkustofnun (Vol. 3, map M9), which think we should point out to *Spölur h.f.* The maps show basicly depths to basement according to the multi-channel seismic reflection data by Orkustofnun. They are identical in this aspect, except that Geoteam has altered the isobaths in a roughly square area about 200 m on each side, located in the deepest sedimentary trough (at approx. coordinates: 428250 N, 687300 E).

This modification is not reported in the text of the report, and the reason for it not explicitly stated. Apparently some misfit between the two types of data, seismic reflection and seismic refraction, was encountered. It can be deduced that the refraction data have been given preference in this small area. The result of this is a smoothing of the extremities of the basement topography, but according to the preferred interpretation of the reflection data a steep basement high is encountered in this area adjacent to a narrow channel, in which the depth to basement is up to 114 m. It should be noted that this is on the proposed tunnel route where the maximum depth to basement is about 116 m, some way to the north. It seems incautious to us to disregard a possible deep channel and associated zone of weakness in this location.

The reflections picked in the reflection data as the basement surface, could possibly be caused other contrasts in the strata. However, another likely cause can be proposed for the discrepancy in the results for the two different seismic methods. According to the report, Geoteam has used interpretation methods which are not suitable for application where a thick overburden layer covers a irregular basement refractor, as in the present case. (These limitations of the methods are in fact stated in the report, see: "Mean-minus-T method", Vol.2, Appendix 1, p.6, last paragraph). These methods have the effect of smoothing out the basement topography, and it should also be realized that there are theoretical limitations to the spacial resolution inherent in the refraction method.

At the end of chapter 4.4 (Vol. 1) is this statement: *"Based on the results from the digital reflection seismics some refraction profiles may have to be re-interpreted. The model used has no influence on the rock-velocities determined by the "mean-minus-T method".* If our understanding of the methods used is correct, as described in Appendix 1 of Vol. 2, this statement is misleading. In this approach to the interpretation problem, the analysis of refractor velocities is as susceptible to errors as the basement topography. This in effect states that the "mean-minus-T method" should not be used in this case, but Hales method (see Appendix 1 of Vol. 2) or an equivalent method should be used.

The result of the exclusion of the previously mentioned channel from the final structure map (33165-2) is that one of the two major "bedrock lineament" have been shifted some 150 m to the north along the tunnel route, as compared to the interpretation of Orkustofnun (Vol. 3, chapter 7.3.2). Other suggestions in our report for the interpretation of fault or fracture lineations have for the most part be ignored. No attempt has been made to correlate observed fault and dyke lineations exposed on the shore with indications on the basement map, and the regional structural trend has been disregarded in suggesting possible lineations. Some lineations, so called "Enscarpments", are indicated on the map. They are presumably meant to suggest lava benches or fault escarpments, but the criteria for the positions and trends are not very clear. Little attempt has been made to correlate these lineations with the observed low-velocity zones.

4. A TECTONIC MAP

It must be important for the tunnel design to know as well as possible the pattern of fractures and zones of weekness in the basement rocks. As far as we know, the available data contain more tectonic/structural information than have been presented. The structure map by Geoteam seems rather incomplete, and for example ignores mapped lineations on shore. A proper structural map must be based on the collected data base from the various surveys. A combined critical review of the reflection, refraction and geological mapping data should be performed. This is best done in cooperation of all parties that have been active in investigation the area on land and at sea. In this way a more realistic structure map may be hoped for. This applies primarily for the area where basement is at greater depth below relatively thick sediments. In the southern more shallow area, the topographical features of the basement are not very clear and do not suggest much structural indications. In this area magnetic measurements are probably most likely to reveal the structural trends.

It is, however very unlikely that it will be possible to detect in the existing data if any of these faults have been recently active, and doubtful that any method can answer that question with any certainty. The reason is, as mentioned above, that on the whole the sediments in Hvalfjörður show very irregular reflection patterns.

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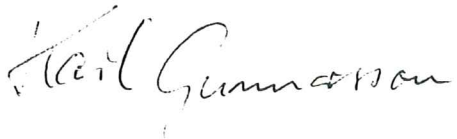

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