Geophysical Downhole Measurements in the Scientific Drillhole HSDP Hilo/Hawaii – Targets and first results of log interpretation.

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The scientific drillhole HSDP at Hilo/Hawaii (Fig. 1) started in March and ended in late September 1999. The project is aimed at the evaluation of geochemical evolution of a shield volcano above an active mantle plume in correlation with the lithological and structural situation. The ending depth of the borehole of phase 2 was 10,200 ft (3110 m). The drillhole penetrated through Mauna Loa and Mauna Kea lavas, with the contact (so called MK/ML interface) between these two volcanoes at a depth of about 800 ft (250 m). The major lithologies that were drilled, are subaerial and submarine rock formations. The subaerial formations are represented by Aa- and Pahoehoe-lavas with minor ash layers, whereas submarine units are mainly massive units, pillow-basalts and hyaloclastites with minor conglomerates.

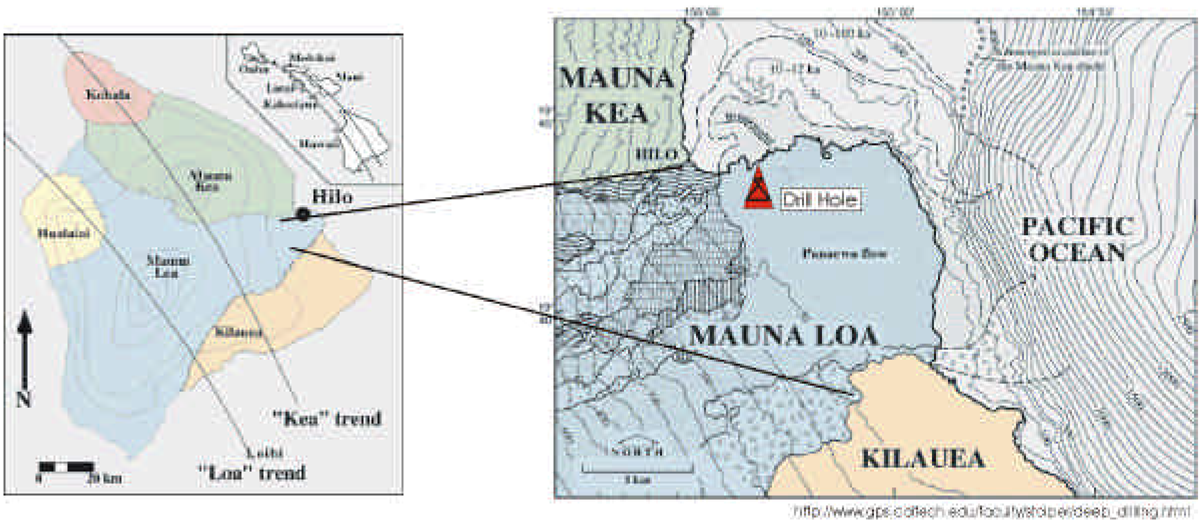

Fig. 1: *Location map of the HSDP drillhole at the 'Big Island', Hawaii, left picture represents the distribution of the different volcanoes which build up the youngest island of the Hawaiian island chain.*

Last year, the GFZ Potsdam performed geophysical downhole measurements in co-operation with the University of Aachen in an open hole in the HSDP drillhole in two stages: the first phase of the logging program was carried out in early August 1999, while the second phase was in early December 1999. The aim of the logging program is to improve the understanding of the hydrological and hydrochemical situation which is closely related to alteration processes and vesicularity of different lava types. Since the structural situation of a volcano is mainly characterized by the different lava flows which build up the volcano, detecting single flows by means of their individual geophysical appearance is one possibility to reach the aim.

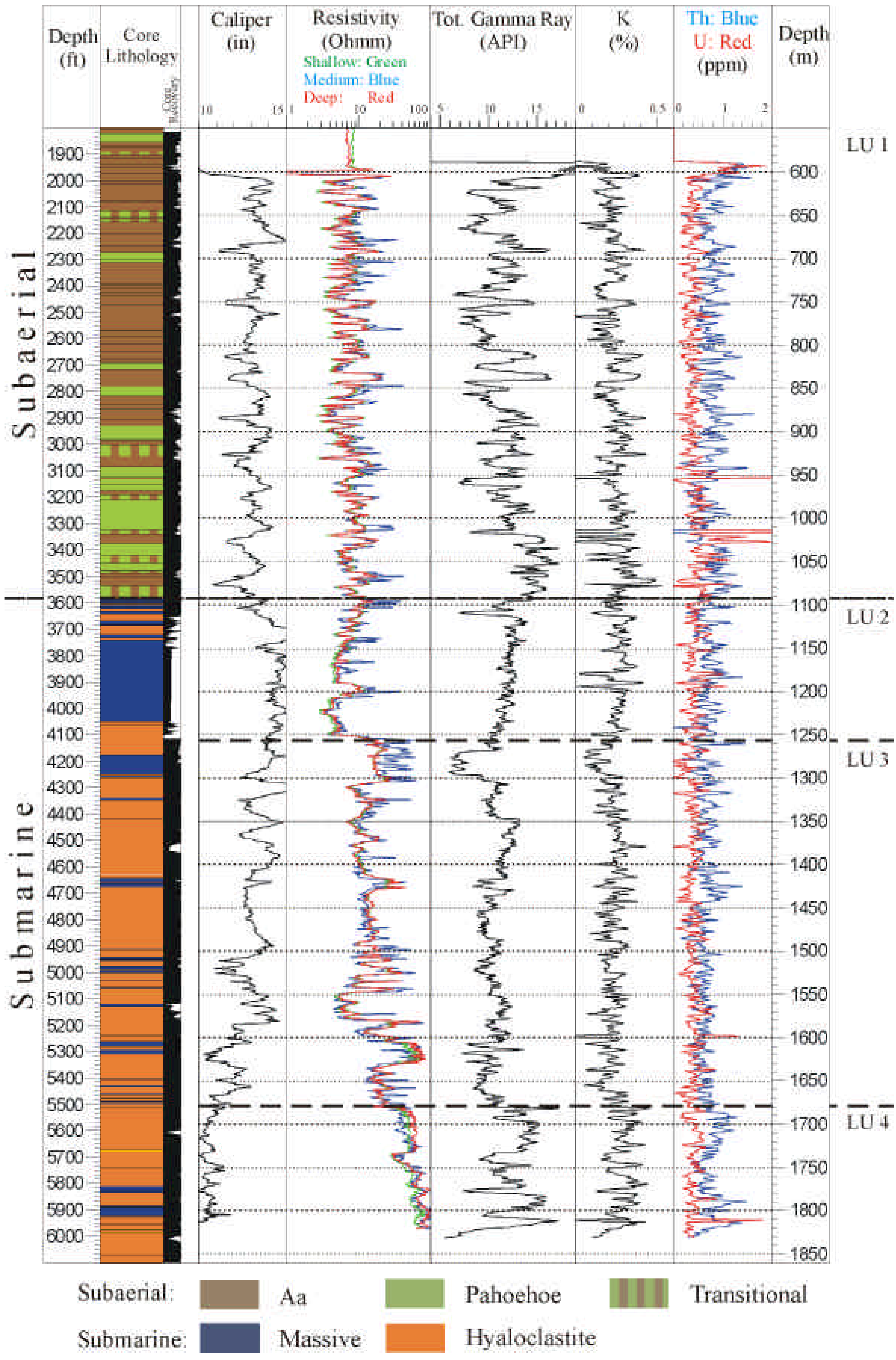

Fig. 2: *Composite log of geophysical borehole data of the first logging campaign in the HSDP-drillhole: the four log units LU 1-4 are mainly characterised by the resistivity and the total gamma-ray log.*

The specific targets of this logging study are:

1. Reconstruction of a detailed lithological profile, including separation of individual lithological units.
2. Evaluation of the BHTV data with regard to stereoscopic analysis of structural elements.
3. Porosity estimations from resistivity and sonic logs in combination with detailed thin section investigations, revealing the role of K-based alteration.
4. Determination of variations of petrophysical in-situ parameter with depth (increasing age); in particular mapping of distribution and extent of alteration and possible fluid pathway zones.
5. Characterisation of fracture zones in correlation with geochemical and petrographical investigations: detection of possible changes in geochemistry, grade of alteration and fracture behaviour.
6. Quantitative and semi-quantitative correlation of geochemical and petrographical core and geophysical borehole data.
7. Integration of borehole data with results of other scientific groups (e.g. temperature measurements, hydraulic experiments, alteration and secondary mineralisation).

The following geophysical measurements have been performed in the first logging program over a depth interval of 1900–6000 ft (580–1830 m) including Borehole Televiewer BHTV, Self Potential Tool SP, Dual Induction Log DIL, with medium and deep resistivity, Laterolog LL3 for shallow resistivity and Spectral Gamma Ray Tool SGR (total GR, K, Th and U). The second logging program includes the measurements Sonic Log BCS, Dual Laterolog DLL and Spectral Gamma Ray Tool SGR (total GR, K, Th and U) 5900-8950 ft (1800–2730 m). Because of the fact that the data are not fully processed, we can only present preliminary results of the first logging program by now.

As a first result, the logged profile (Fig. 2) indicates a division of the lithological profile into the subaerial (1900–4100 ft, 580–1250 m) and the submarine zone (4100–6000 ft, 1250–1830 m). According to their geophysical appearance the submarine zone can be further subdivided into at least three zones, revealing a general subdivision of the two main zones into four log units LU 1-4.

The basaltic lava flows of the first zone (log unit 1) consisting of Aa- and Pahoehoe-Lavas show high total GR and low resistivity values in general. These flows do not only reveal a great variation in resistivity and gamma ray activity between different flow types, but also within single lava flows (Fig. 3a). High total GR values seem to be correlated to higher K content and appear in rocks with low olivine content and sparse vesicularity. Low resistivities are mainly caused by high vesicularity and rubble zones, situated at top and bottom of the flows.

Although log unit 2 shows resistivity values similar to the subaerial zone, but with lower GR variations, its rock content can be compared to those of the submarine zone: it consists of hyaloclastites with different amounts of basaltic lithoclasts and pillow basalt layers, which characteristically show low gamma ray activities. The low resistivities might be due to less compaction and highly rubbing of the unconsolidated sediments, thus causing less core recovery. Therefore this unit has a transitional character for some reason.

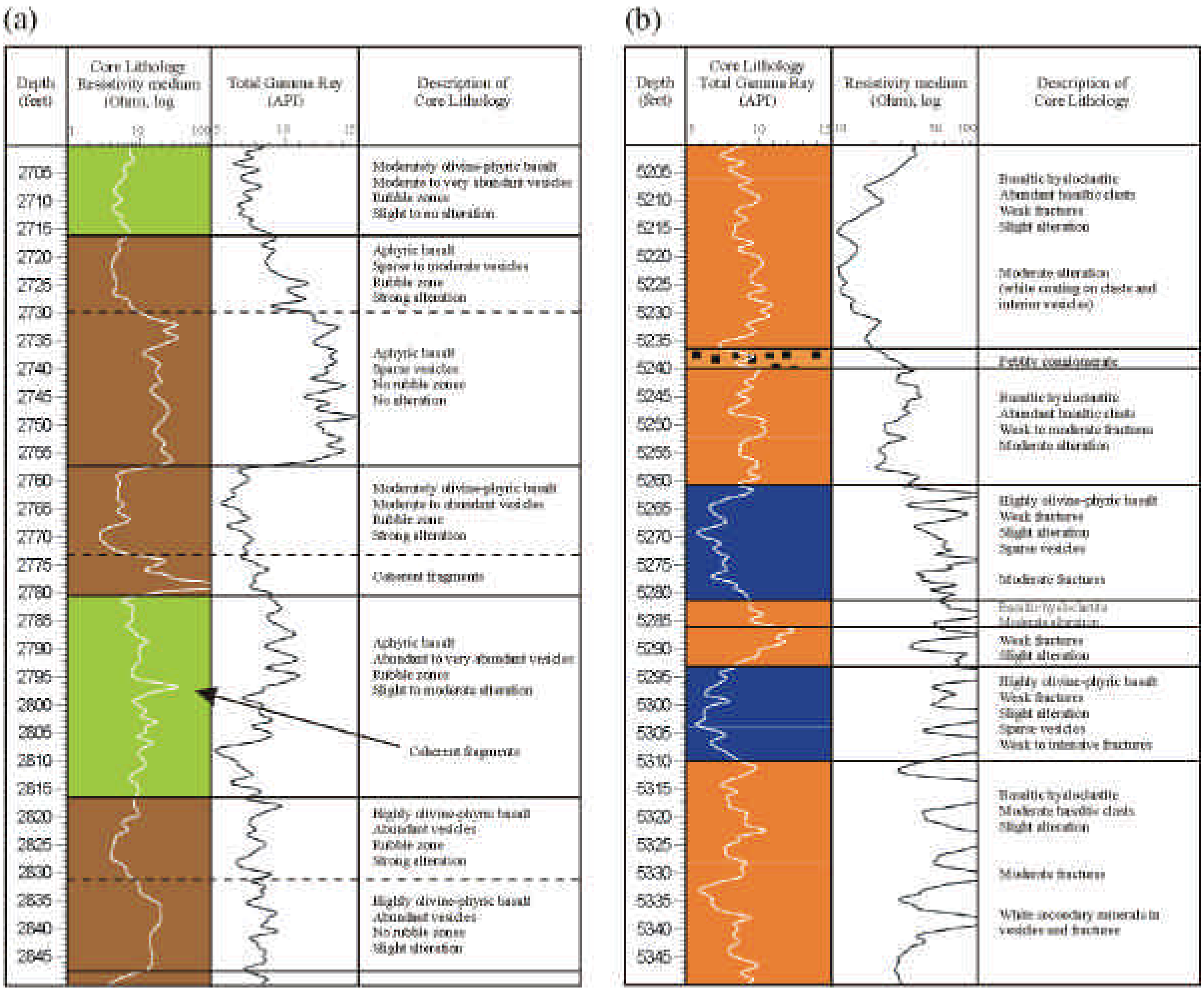

Fig. 3: *Examples for detailed comparison between geophysical borehole data and core lithology from (a) subaerial and (b) submarine section.*

In contrast, the submarine rocks of log unit 3 and 4 reveal higher resistivity values of the hyaloclastites, probably due to better rock conditions in general. In log unit 4 (Fig. 3b) resistivity values even increase compared to log unit 3, suggesting a higher compaction grade in combination with a beginning secondary mineralisation in vesicles and fractures. Higher resistivities do not only seem to contribute to one rock type but might also be controlled by alteration effects. The diverting effects between deep, medium and shallow resistivity measurements which cannot be observed in the other log units above, contributes to different borehole effects controlled by the size of mud invasion zone, which in this case is rather low. An increasing total GR towards the depth might be indicative for a change in alteration type, which can be attributed to a change in porosity fluids.

In general, subaerial lava flows and submarine massive units show the same geophysical response (Fig. 3), although caused by different geological effects: whereas the lava flows are mainly characterised by rubble zones, due to high vesicularity, the massive rocks are partly influenced by strong fracturing, causing possible fluid pathways. In order to solve this and other questions, further investigations including geochemical analysis and studies on thin sections will be applied in combination with a detailed log interpretation of the current and the second logging campaign.