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NATURAL GAMMA LOGGING OF BOREHOLE I ON VERNAGTFERNER (OETZTAL ALPS, AUSTRIA)

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With 3 figures

SUMMARY

Natural gamma logging was executed in borehole I on the Vernagtferner (Oetztal Alps, Austria) down to a depth of 60 m below surface. The radioactivity profile reflects the atmospheric injection history. Above a borehole depth of 28 m the log is enriched in bomb produced ^{137}Cs along with ^{40}K and elements of the uranium series. The highest gamma level, which originates from 1963 precipitation with high fallout load, is found in a depth of 18.5 m.

GAMMA-RAY-LOG DES BOHRLOCHES I AUF DEM VERNAGTFERNER (ÖTZTALER ALPEN, ÖSTERREICH)

ZUSAMMENFASSUNG

Im Bohrloch I auf dem Vernagtferner (Ötztaler Alpen, Österreich) wurde ein Gamma-Ray-Log bis zu einer Tiefe von 60 m unterhalb der Gletscheroberfläche gefahren. Das Log spiegelt die zeitliche Folge von thermonuklearen Waffentests in der Atmosphäre wider. Oberhalb von einer Tiefe von 28 m ist im Log das radioaktive Spaltprodukt ^{137}Cs neben natürlichem ^{40}K und Elementen der Uran-Zerfallsreihe nachgewiesen. In 18,5 m Tiefe wird der höchste Gamma-Pegel und damit eine Zeitmarke für 1963 nachgewiesen, als in der Atmosphäre der maximale radioaktive Fallout gemessen wurde.

1. INTRODUCTION

During the last decades investigations on radioactive isotopes of both natural and of nuclear bomb test origin have been carried out on temperate alpine glaciers. Characteristic radioactivity levels of the fission products attached to particles in the snow can be ascribed to the time scale of the bomb test history from 1952 to present day. Among the radioactive fission products which are deposited in glacier firn by atmospheric fallout, ^{137}Cs is strongly adsorbed by dust particles which are concentrated at the glacier surface in ablation horizons. When the horizon is buried under the accumulation of subsequent years no further redistribution of the ^{137}Cs fission products takes place, since ^{137}Cs is not washed out during periods of melt and by rain. Its activity is secondarily enlarged as the ablation horizon acts as adsorption filter for the percolating melt water (Prantl et al., 1972, Ambach et al., 1976, Nijampurkar et al., 1982, Jouzel et al., 1977).

Usually the studies involve the collection of cores which are prepared and low-level counted in the laboratory. Dating of ice cores from Vernagtferner (Oetztal Alps, Austria) with fission products and tritium are reported in this volume by v. Gunten et al. (1982) and Oerter and Rauert (1982). This paper aims at the use of an in situ spectrometer for the investigation of radioactivity profiles with depth as proposed by Pinglot and Pourchet (1981). Preliminary results of borehole I on the glacier Vernagtferner are discussed.

2. EXPERIMENT

We applied a logging system normally used for geohydrological investigations. The down-hole tool consists of a scintillation detector with a 3 ″ × 2″-NaI (Tl)-crystal. The probe is lowered down by a winch at a speed of 1 m/min. The surface electronics, which supply power to the down-hole probe and condition the returning signals, include a 1024 channels pulse height analyser.

By our logging system we measure both the natural and the bomb produced gamma radioactivity in a borehole as function of depth. The natural terrestrial radioactivity depends mainly on the content of elements in the uranium and thorium series and also of radioactive potassium. The radioisotopes are distinguishable by their different gamma energy. For example, thorium can be identified by its gamma radiation peak of 2.62 MeV (^{208}Tl), uranium by its 1.76 MeV peak (^{214}Bi) and potassium by its 1.46 MeV peak (^{40}K).

The most dominant injection of the artificial radionuclides into the atmosphere occured in the early 1960's as a result of nuclear weapon tests which followed the bomb moratorium of 1959 which caused a decrease in the fallout. The chronology of the radioactive atmospheric fallout is recorded by a worldwide network, where total

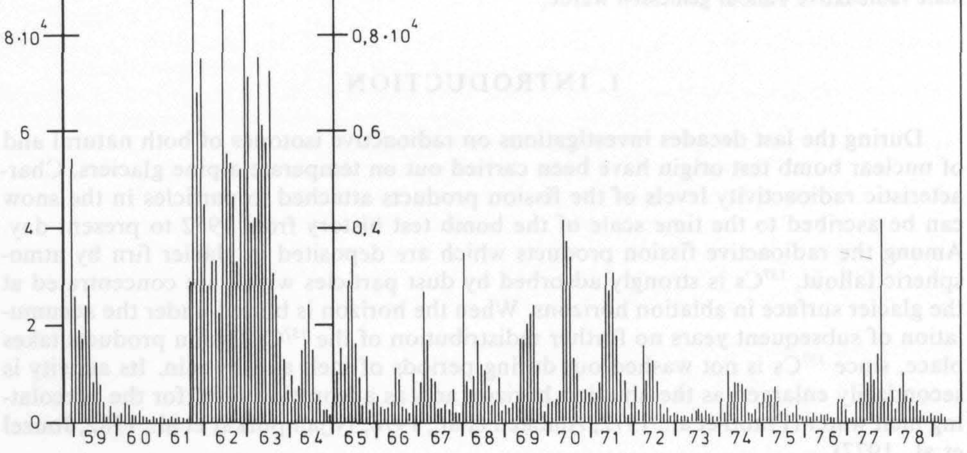

Fig. 1: Total beta-radioactivity in precipitation at station Garmisch-Wank (FR Germany) in an altitude of 1780 m a. s. l. (Kirchlechner, 1979)

beta activity of air and precipitation is measured. At the station Garmisch-Wank (FR Germany) the highest level of radioactivity was registered in 1963, which exceeds more than 10 times present-day annual peaks (fig. 1).

Among the gamma emitting fission products only ^{137}Cs is a valuable tracer for radioactive dating studies over several decades on temperate glaciers. Other bomb produced gamma emitters like ^{125}Sb, ^{144}Ce, ^{88}Y etc. are negligible since their half life is relative short, less than 3 years. The half-life of ^{137}Cs is 30 years and its gamma energy is 0.66 MeV which may be overlapped by 0.61 MeV gamma of ^{214}Bi.

3. RESULTS

From 21 through 22 July 1982 natural gamma logging of borehole I was carried out on the Vernagtferner. The results are given by fig. 2 and fig. 3. Fig. 2 shows the gamma log down to a borehole depth of 60 m and fig. 3 gives the gamma-ray spectrum taken at a depth of 18.5 m below the top of the access tubing (≙ 3154.8 m a. s. l.). A second spectrum taken at a depth of 22.5 m yields the same gamma energy distribution as shown in fig. 3. Further gamma spectra were not measured since the necessary counting time lasts more than 50000 s.

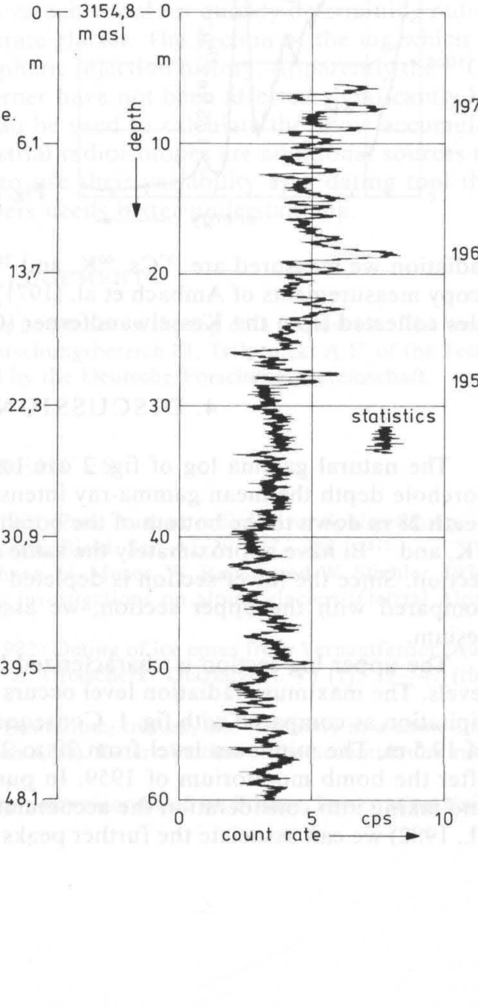

Fig. 2: Natural gamma log of borehole I on the Vernagtferner

The gamma log shown in fig. 2 is recorded in relative activity units (cps) because our detector was not calibrated for these measurements. The dynamic response of the log allows a vertical resolution of better than 0.3 m. The log is not corrected for formation density and borehole caliber. Gamma radiation of the formation is buried beneath cosmic radiation down to a depth of 5 m, and as a result the interpretation of log data above this depth was not possible. According to fig. 3 the principal sources of gamma radiation we measured are ^{137}Cs, ^{40}K, and ^{214}Bi. This is in contrast to gamma spectroscopy measurements of Ambach et al. (1971) who detected only ^{137}Cs in firn layer samples collected from the Kesselwandferner (Oetztal Alps).

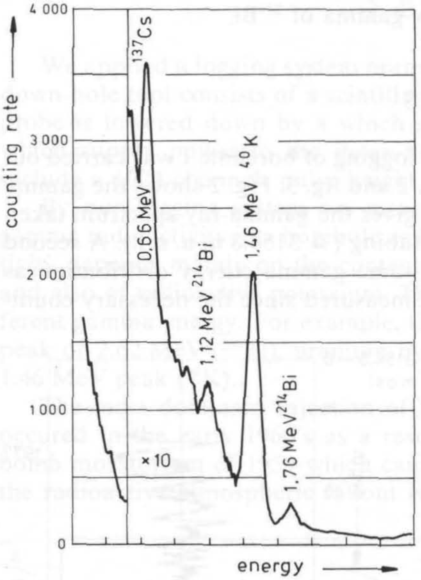

Fig. 3: Gamma spectrum of borehole I at a depth of 18.5 m

4. DISCUSSION OF RESULTS

The natural gamma log of fig. 2 can be divided in two sections. From 5 to 28 m borehole depth the mean gamma-ray intensity is about 5 cps. It is only 3.5 cps underneath 28 m down to the bottom of the borehole. From a qualitative point of view ^{137}Cs, ^{40}K, and ^{214}Bi have approximately the same source strength (see fig. 3) in the upper log section. Since the lower section is depleted in its radiation level by about one third as compared with the upper section, we assume that it contains no bomb produced cesium.

The upper log section is characterized by a sequence of extremes of radioactivity levels. The maximum radiation level occurs at a depth of 18.5 m and reflects 1963 precipitation as compared with fig. 1. Consequently 1962 precipitation is found at a depth of 19.5 m. The minimum level from 20 to 21.5 m depth identifies the fallout decrease after the bomb moratorium of 1959. In pursuing the comparison of fig. 2 with fig. 1 and taking into consideration the accumulation history of the Vernagtferner (Oerter et al., 1982) we can associate the further peaks to the annual fallout maxima. The peak of

7 m depth corresponds to 1977 and the 28 m peak to 1953 precipitation. In general the separation of the annual log peaks differs from about 0.5 m to about 2 m.

The sequence of radioactivity levels provides a means of determining the accumulation rate on the Vernagtferner. In the upper section of the borehole I 9.5 m or 8.3 m w. e. are accumulated from 1953 to 1963 and 11.5 m or 8.3 m w. e. from 1963 to 1977. From this figure we arrive at a yearly accumulation rate of 0.68 m w. e. from 1953 through 1977 respectively 0.81 m w. e. from 1953 to 1963 and 0.59 m w. e. from 1963 to 1977. For the time span from 1979 to 1982 we get 2 m w. e. snow accumulation respectively 0.67 m w. e. per year by comparing our log data with the tritium profile of the core I which was drilled in 1979 (see fig. 2 in Oerter and Rauert, 1982).

The lower section of the log is widely smoothed as compared with the upper one. Nevertheless we observe variations of the gamma level with depth which fairly exceed statistical fluctuations. At present the occurrence of these variations and their correlation to the dust layers ascertained by the core drilling of borehole I (see fig. 4 in Oerter et al., 1982) need further explanation.

5. CONCLUSION

Natural gamma logging proved to be a valuable tool for quickly determining radioactivity profiles of a borehole on a temperate glacier. The section of the log which is enriched in fallout ^{137}Cs reflects the atmospheric injection history. Apparently the ^{137}Cs profiles from borehole I on the Vernagtferner have not been affected significantly by isotopic homogenization processes and can be used to calculate the snow accumulation over the last 3 decades. Natural terrestrial radioisotopes are additional sources of count rates of the gamma log. In order to use their variability as a dating tool the mechanism of their deposition on firn layers needs better understanding.

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