Ice Thickness and Subglacial Topography Studies by Ground Penetrating Radar during the XX Indian Antarctic Expedition

J.T. GERGAN and RENOJ J. THAYYEN
Wadia Institute of Himalayan Geology, Dehradun, Uttaranchal
E-mail: glacierdb@redifftnail.com

Abstract

Ground Penetrating Radar (GPR) over the years has proved to be a versatile tool for mapping of glacial ice thickness and related studies. During the XX Indian Antarctic Expedition pulse EKKO IV GPR operating at center frequency of 12 MHz was used to measure the ice thickness of polar ice sheet to the south of Schirmarcher Oasis Queen Maund Land in Eastern Antarctic The GPR profiling was carried out between Vetehiea (70. 47.85 S, 11.32.45 E) Tallaksenvardan (70.51.58 S, 11.32.45 E) nunataks a distance of 8.3 km The general bedrock topography is gently undulating, 1520 m wide depression in the bed rock is marked by a sudden break in slope at 4700m and 6220 m due south of Vetehiea, where the thickness of ice is more than 440m, indicating a fault controlled depression in the bed rock. The extension of southern edge of this depression was traced 700m due NW from Tallaksenvardan two kilometer due west of Vetehiea Tallaksenvardan GPR survey line, with this it is established that the alignment of rift like depression is due NE SW, This alignment is parallel to number of fault escarpment and shear zones in Schimacher Oasis. Detailed subglacial topographic mapping would go long way in delineating and better understanding of the sub glacial tectonic features of rocks under polar ice south of Schirmacher Oasis and selection of a suitable site for ice core drilling.

Introduction

Glaciers and Ice sheet play an important role in understanding of past and present climatic, atmospheric, nuclear and environmental events is well established. National Center for Antarctic and Ocean Research (NCAOR), in an effort to plan out systematic studies of polar ice invited Wadia Institute of Himalayan Geology (WIHG) to pool in their efforts by conducting Ground Penetrating Radar (GPR) studies of polar ice to identify a suitable zone close to the Indian Antarctica Research Station Maitri for detailed studies of polar ice. GPR has emerged as one of the most successful geophysical techniques for the study and mapping of glacier ice thickness and related studies of glacial ice. The first measurements of polar ice thickness by radar reflections were carried out

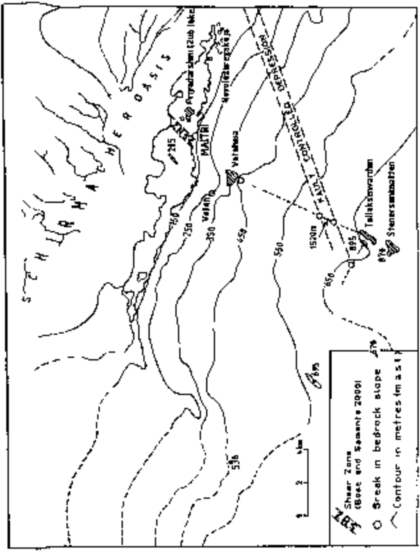

Fig .1 *.Location map of GPR. survey profiles*

by Jiracek and Bentley in January 1965 at South Pole Station (Jiracek, 1967). Drewry (1971) investigated subglacial topography between the Southern Trans-antarctic Mountains and South Pole. Drewry (1975) identified three groups of subglacial topographies, one comprising lowland areas, and the other two highland regions, one with relatively smooth and regular topographic surface but dissected by deep valleys, and the other showing a very rugged mountainous terrain.

During the XX Indian Antarctic Expedition, GPR profiling was carried out for a distance of 8.3km. starting from near the south of Vetehiea (70. 47.85 S, 11.32.45 E) and ending to the north of Tallakserrvardan (70 51.58 S, 11.32.45 E), and to the south of Schirmacher Oasis, Queen Maudland, Eastern Antarctica (Fig.l). The survey line almost coincides with a polar ice divide demarcating two distinct ice flow directions, flowing NW and NE. The major objectives of this work were (i) to locate a suitable zone in polar ice close to Schirmacher Oasis for conducting detailed studies of polar ice, especially to study the imprints of past and present climate change; (ii) to map the subglacial topography with special emphasis on the demarcation of structural inhomogeneities such as faults and shear zones beneath the polar ice; and (iii) to decipher the tectonic setup of the region.

GPR Survey

Pulse EKKO IV GPR of Sensors & Software, Canada, was used for the polar ice thickness measurements. Antenna with a central frequency of 12.5 MHz with a pulse width of 2.4 ns powered by a 20 kw transmitter was used for the GPR profiling. The profiling was carried out between Vetehiea (70. 47.85 S, 11.32.45 E) and Tallaksenvardan (70.51.58 S, 11.32.45 E) (Fig.l), a distance of 8.3 km with antenna separation of 8m with a step size of 2m CMP surveys were conducted for near surface velocity measurements (c.f. Gergan et al. 2001). The survey line was marked by GPS at an interval of hundred meters for entire length of 8.3 km.

Results and Discussion

Profiles were processed and plotted using EKKO COLOR program (Fig 2). Thickness of polar ice sheet at the staring point of GPR profiling on the southern edge of Vetehiea is 5 to 7m The ice thickness increases gradually due South all along the survey line. The bedrock ice interface slopes at an angle of 20 degrees till 800m from the starting point, then it suddenly flattens out to 6 to 8 degrees. After this break in bedrock slope, the surface of bedrock is undulating.. The ice thickness increases to 320 m at 1400 m from the starting point, and then it increases to 380 m at 2700m. At 4700 m point, the bedrock slopes towards south, and gradually the ice thickeness increases to 440m. From this point, the pulse EKKO IV GPR with the team could not deduct the ice

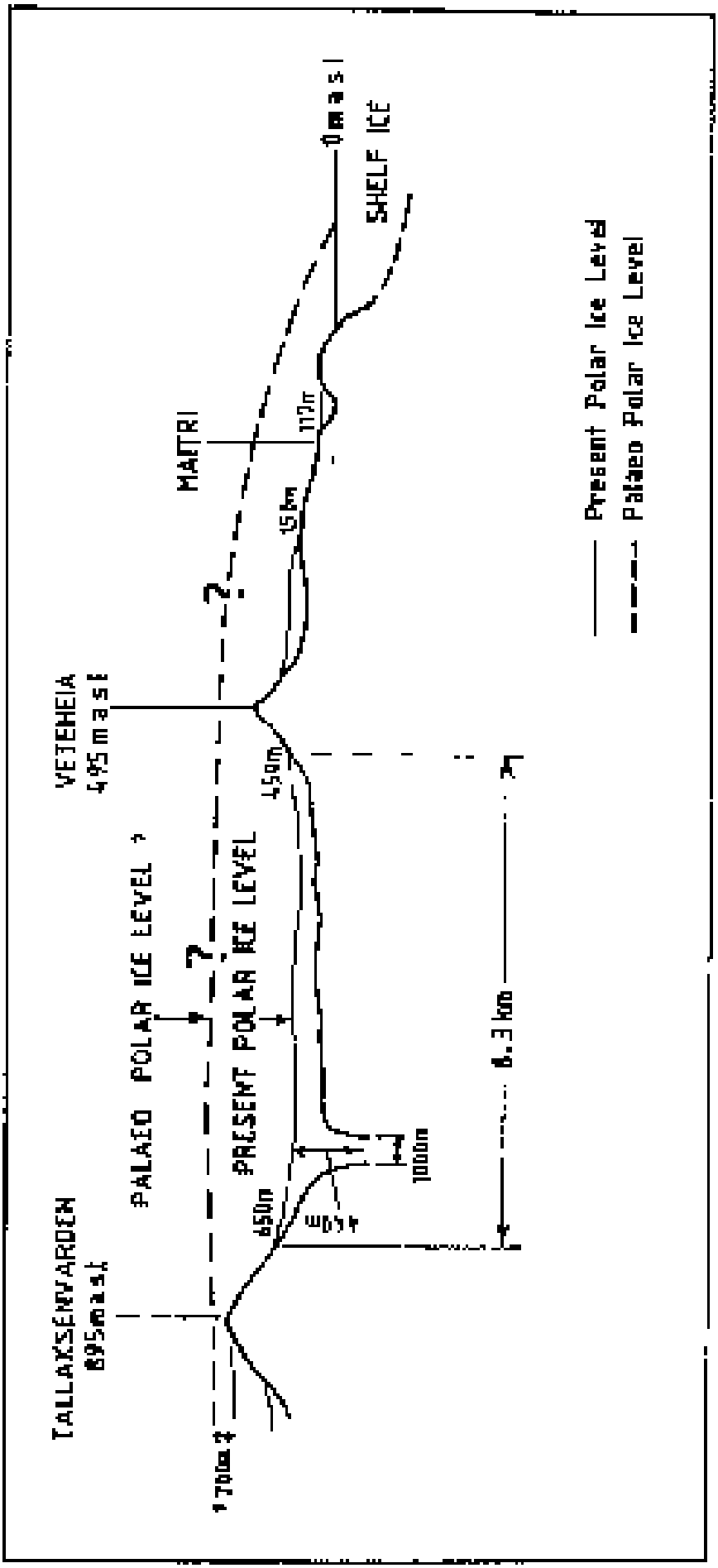

Fig .2 .*Schematic .section. south of Maitri Schumacher Hills of polar ice based on GPR data.*

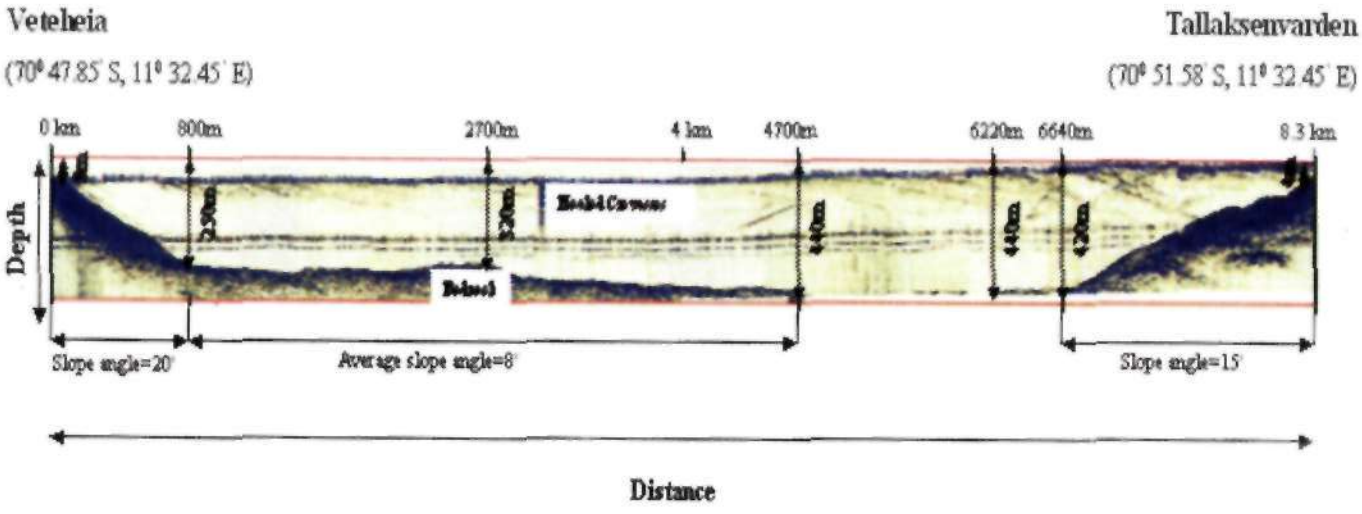

Fig.3. *GPR profile from Veteheia to Tallaksenvarden (8.3 Km).*

bedrock interface. Beyond this point, it is inferred that the thickness of polar ice is more than 440m due south along the survey line towards Tallaksenvardan. The bedrock ice interface was again encountered at 6220 m point from starting point and 2080m due north from Tallaksenvardan. The sudden break in slope at 4700m and 6220m points to a 1520m -wide deep fault-controlled depression in the bedrock beneath the polar ice. The Western extension of the southern edge of the fault-controlled depression was traced 700m NW of Tallaksenvardan and 1.5 km SW from the Vetehiea. The direction of the depression is almost parallel to the shear zones mapped by Bose and Samata (2000) and the fault traces mapped by Ravindra (1999). The subglacial topography is relatively smooth and dissected by deep rift-valley type feature very similar to that described by Drewy (1975) in Eastern Antarctica. The bed rock slope increase sharply 15 degrees at 6800m and remains more or less constant till it meets the survey line at 8300m the northern edge of Tallaksenvardan nunatak and the end of GPR survey line.

A healed crevasse at 2920 m from staring point has been identified by the sudden change in the reflection pattern in the profile. Many reflections from surface cracks in polar ice between 3000-5000m are seen in the profile. Two crevasses are identified by their typical hyperbolic reflection pattern, one at 3050m and other at 3700m. Reflection pattern of polar ice in the profile suggests a northward flow of polar ice.

Past extent of polar ice is marked by the presence of erratic boulders at the top and slopes of Vetehiea (495 m.a.s.l) and Tallaksenvardan (895 m.a.s.l), which arc nearly 50rn to 250 m higher than the present polar ice level. Considering the size of erratic boulders it can be presumed that the thickness of polar ice must have been nearly 200 to 300 meters thicker in the past than the present average thickness of 280m in the vicinity of Vetehiea and Tallaksenvardan (Fig 3). Subglacial debris emerging on surface of polar ice to the south of Vetehiea indicate N and NE movement of polar ice as deciphered from orientation of the longer axis of the emerging subglacial boulders, near the starting point of GPR profiling survey line. From these studies it is very evident that there is a need of detailed GPR studies of polar ice to get in depth understanding of polar ice and to decipher the subglacial geology and tectonics, especially neotectonic activities of the region.

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