Electrical Conductivity Characteristics of a Shallow Ice Core from GV7, East Antarctica

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Electrical conductivity of ice core surfaces is known to be proportional to the acidity of ice. A fallout of volcanogenic aerosols, especially sulfuric acid, nitric acid, hydrochloric and hydrofluoric acids, noticeably increases acidity in ice cores. Peaks detected by the electrical conductivity measurement (ECM) can then indicate volcanic activity in the past. If an ECM peak can be related to history of volcanic eruption, this can be used to date ice cores.

We applied the ECM to a 78 m long ice core drilled at GV7, East Antarctica to detect the conductivity peaks produced by volcanic activities and to use them as time markers. During the last 203 years covered by the GV7 shallow ice core, we detected the conductivity peaks resulted from the eruptions of Pinatubo (1991 AD), Tarawera (1886 AD), Krakatau (1883 AD), Coseguina (1835 AD), Galungung (1822 AD) and Tambora (1815 AD).

From some of deeper ice core sections, conductivity varied seasonally in accord with the oxygen isotope ratio ($\delta^{18}O$). In addition, the conductivity gradually increased to a depth of critical density. This study suggests that the ECM can be a useful tool for understanding the depth-age relationship and physical and chemical properties of ice cores.

Study area & Ice core samples

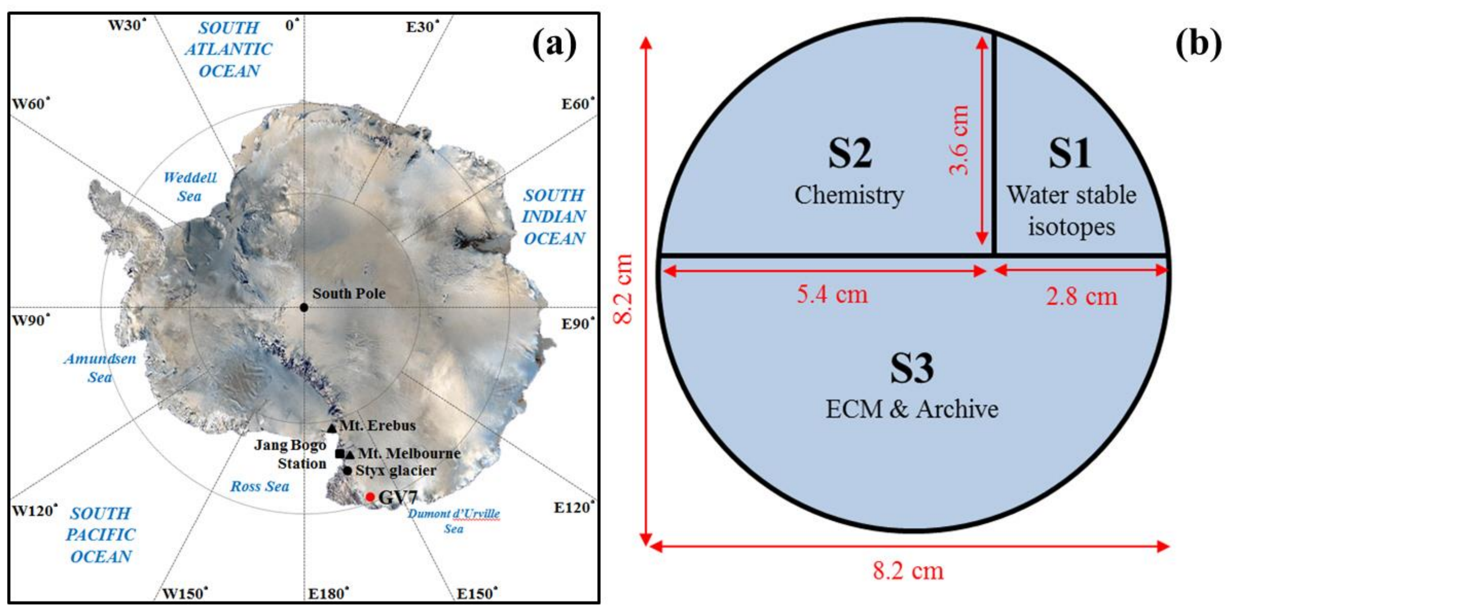


Fig. 1. (a) The GV7 drilling site (70˚41'S, 158˚52'E; elevation 1950m) **(b)** Ice core sectioning strategy as defined by the GV7 Ice core (Depth: 78 m).

Method

Fig. 2. The ECM instrument used (Portable ECM unit, Icefield Instruments Inc. Canada) consists of two electrodes with 20 mm spacing. Two electrodes are dragged in a zig-zag (to minimize the influence of air bubbles and other causes of poor contact) at voltage of 1000 VDC. A trimming blade used to prepare a fresh, flat surface along the length of the core (measured at -14 ℃ ±2). It was measured 3 times to calculate the representative values. The spatial resolution of the measurement is about 5 mm.

Results

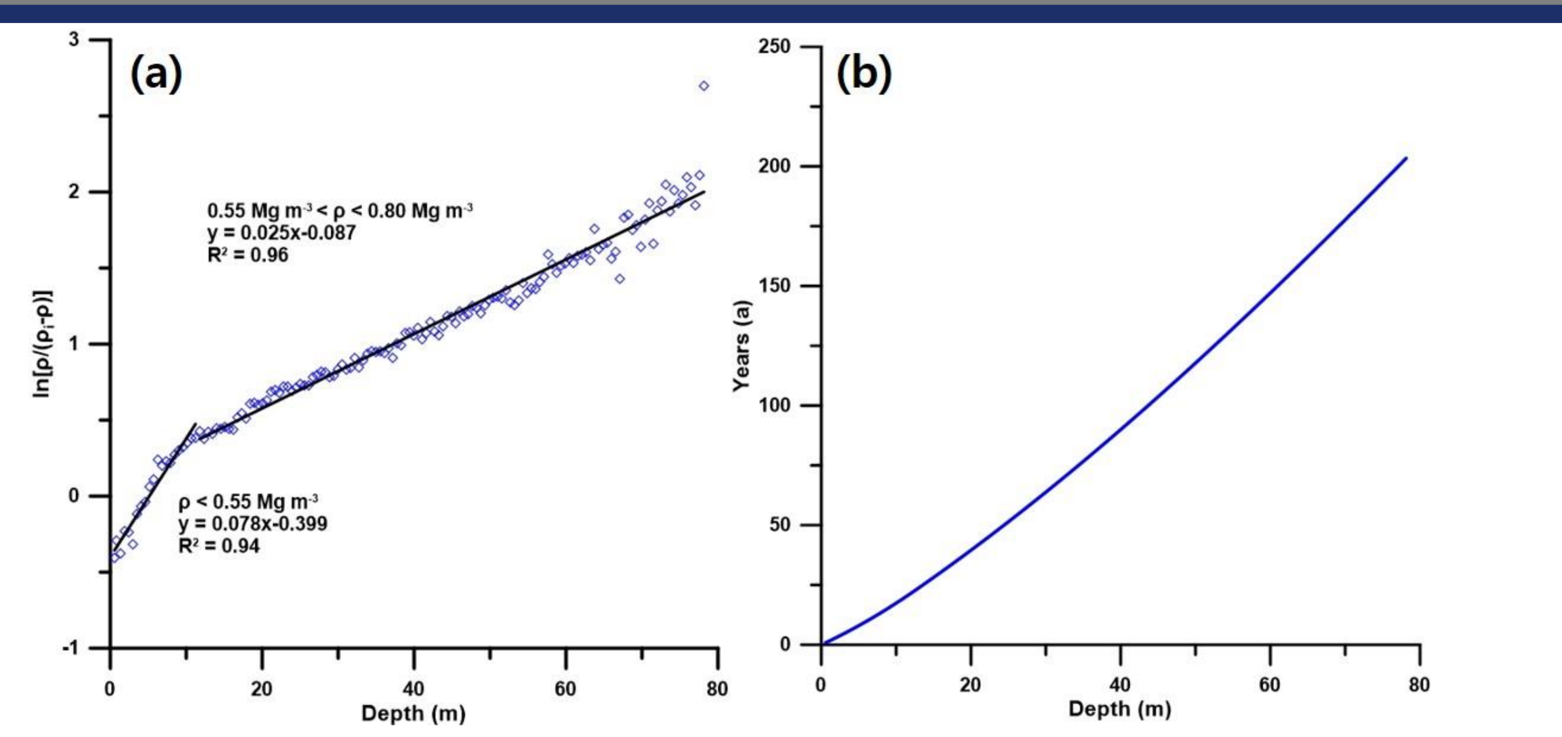


Fig. 3. (a) The relationship between $\ln[\rho/(\rho_i-\rho)]$ and depth. The black solid lines stand for linear regression lines for the density intervals of $\rho<0.55$ Mg m^{-3} and $0.55< \rho <0.8$ Mg m^{-3}. (b) The depth-age model based on the Herron-Langway firn densification model. The age at the bottom of the GV7 shallow ice core was estimated to be 203(±8) years.

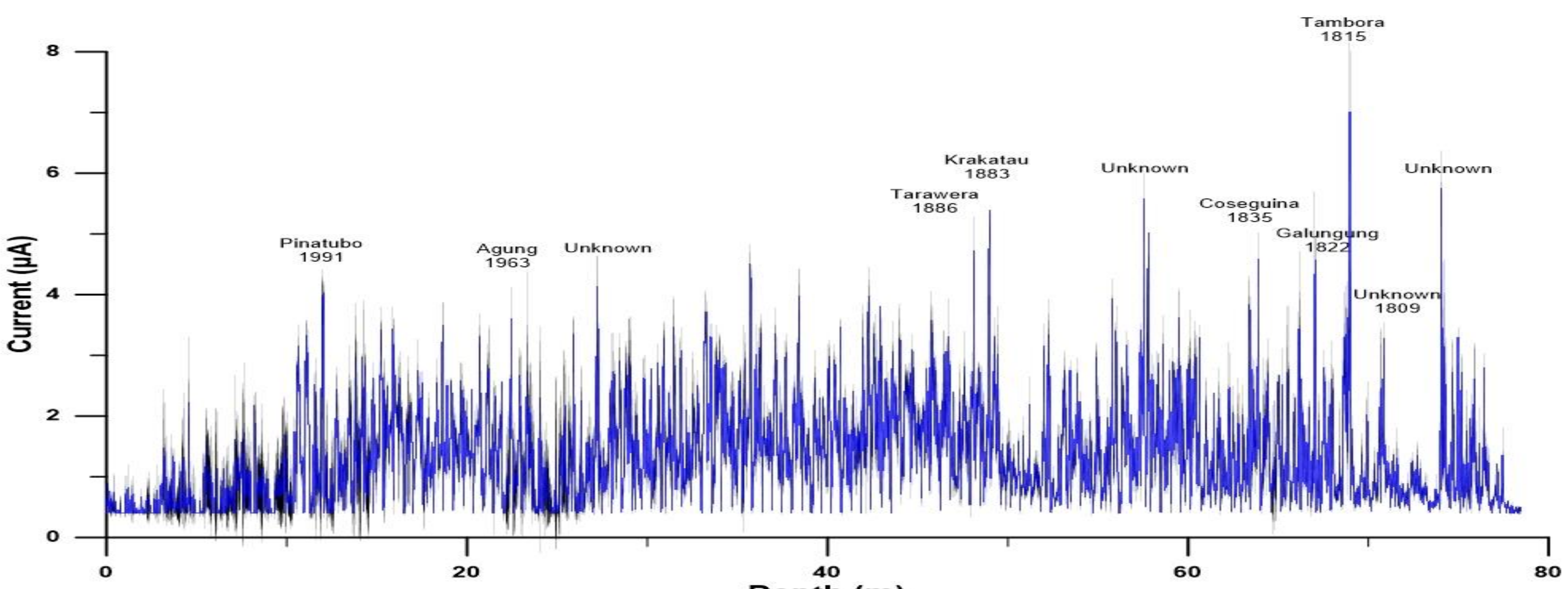


Fig. 4. Electrical conductivity versus depth for the whole core. Shaded line in gray behind the blue line provide an standard deviation of representative values. About 10 volcanic signals appeared in GV7 shallow ice core. Red peaks are explained below.

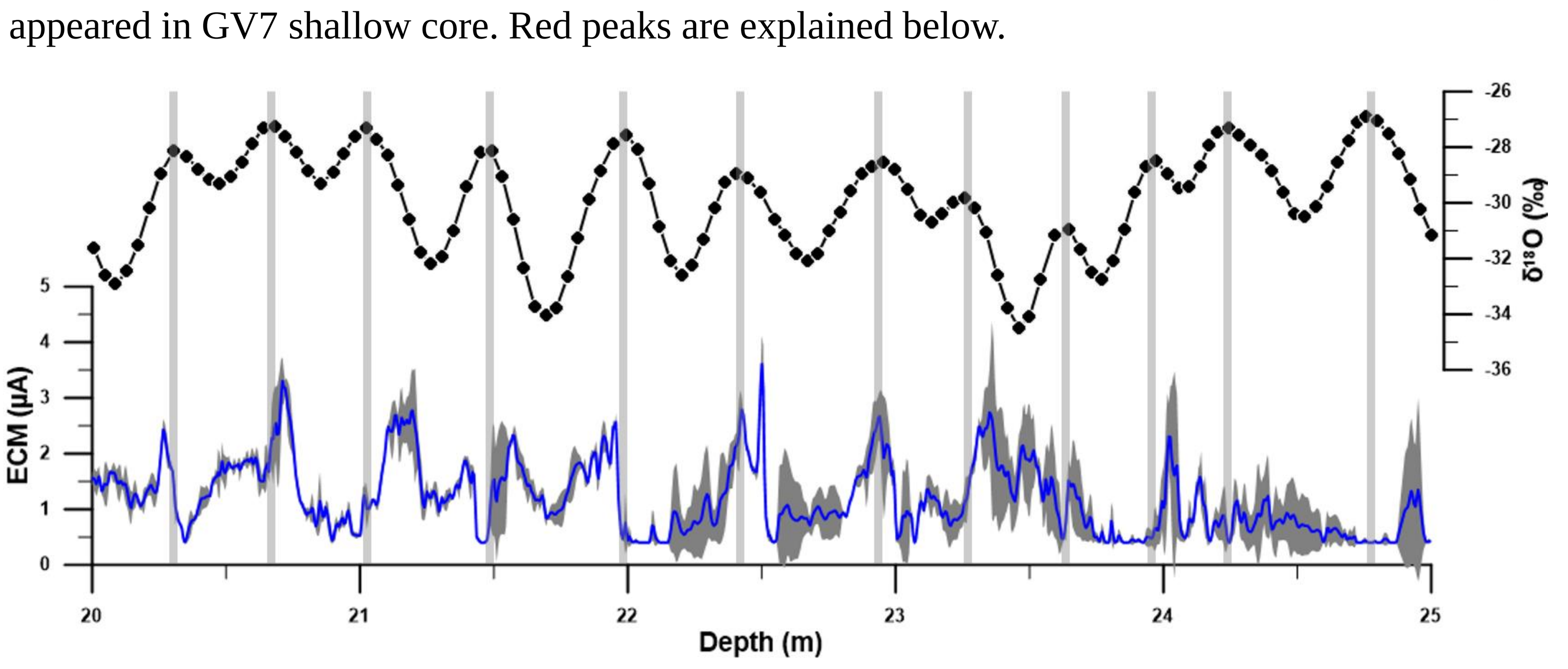


Fig. 5. Seasonal variation in conductivity observed by comparison with $\delta^{18}O$.

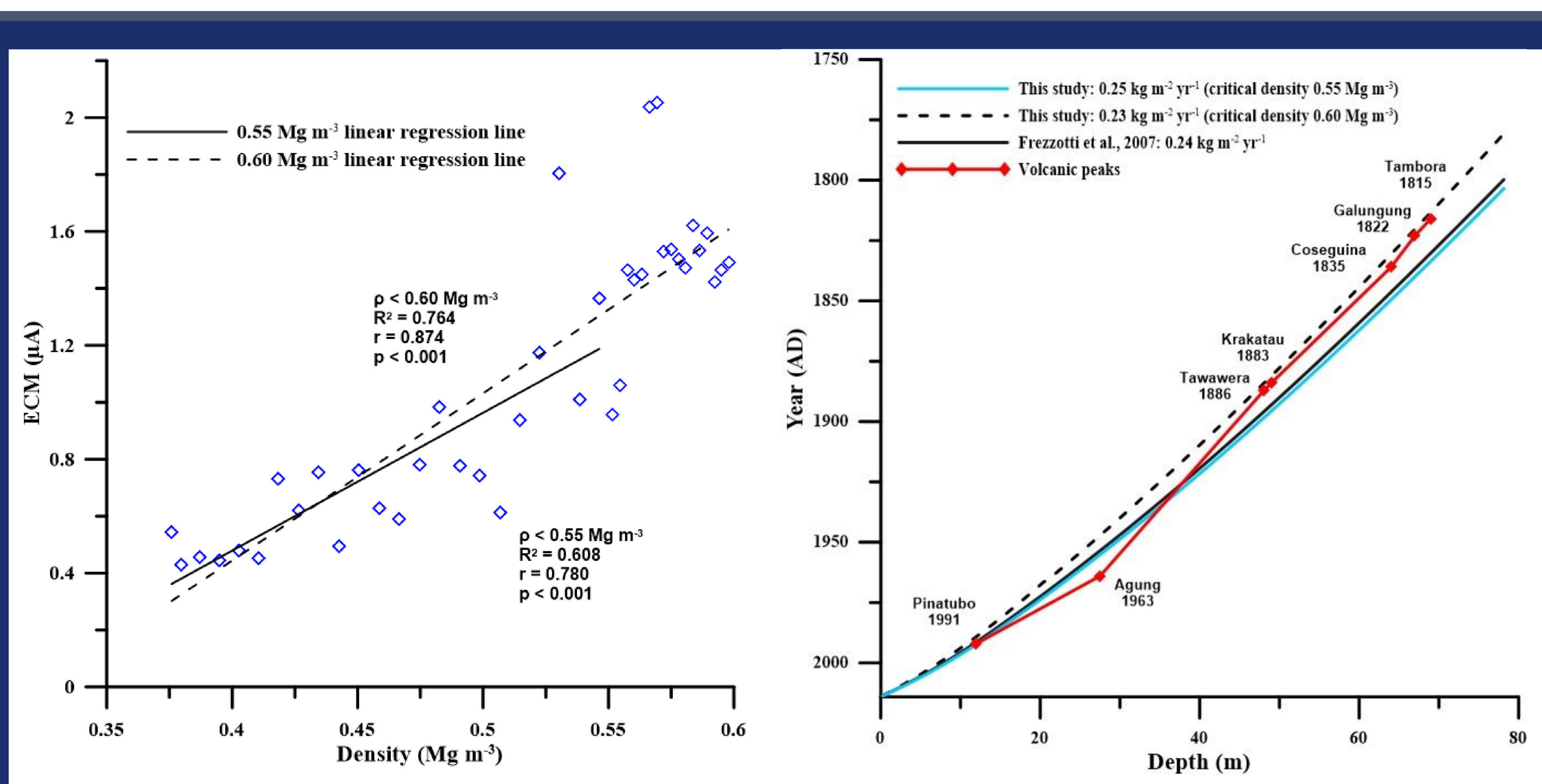


Fig. 6. (a) The relationship between conductivity and density above the critical density. The solid and dotted line indicate the linear regression lines for $\rho<$ 0.55 Mg m^{-3} and $\rho<$ 0.60 Mg m^{-3}, respectively. **(b)** Depth-age relationships built for different accumulation rates. The accumulation rates were estimated from the Herron-Langway firn densification model, previous study and volcanic peaks. The eruption of Agung, 1963 not appeared in GV7 shallow core. The non-sea-salt sulfate data in S25 core could not show the major volcanic eruptions such as Agung 1963 [Watanabe et al., 1999]. The Agung event could be also not be seen in the H15 core [Kohno et al., 1996].

Discussion

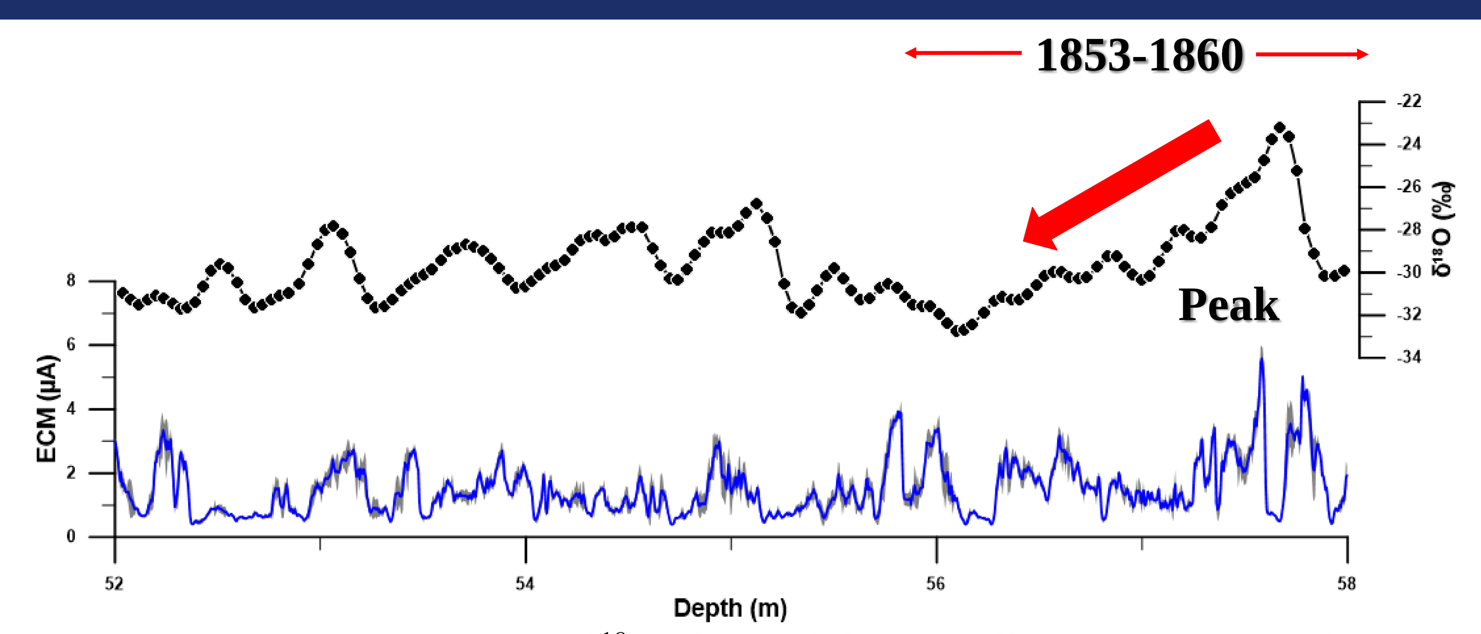
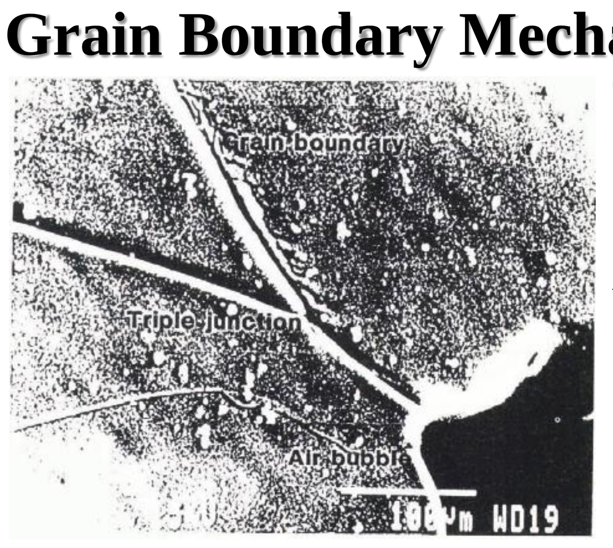


Fig. 8. Oxygen isotope composition ($\delta^{18}O$) dropped dramatically in 1853-1860. The eruption of Shiveluch located in Kamchatka Krai, Russia in 1854 is unlikely the source of the conductivity due to its remoteness.

Conduction Mechanism

Grain Boundary Mechanism



This theory suggests that conductivity take place through a network of liquid veins connected in triple junctions on the grain boundaries(Wolff et al., 1997), and is based on observations of acid anions in triple junctions and veins(Mulvaney et al., 1998).

Critical density

-Snow-firn transition 0.50-0.65 Mg m^{-3}
-0.70-0.75 Mg m^{-3}
-Bubble closed-off / Firn-ice transition 0.80-0.84 Mg m^{-3}

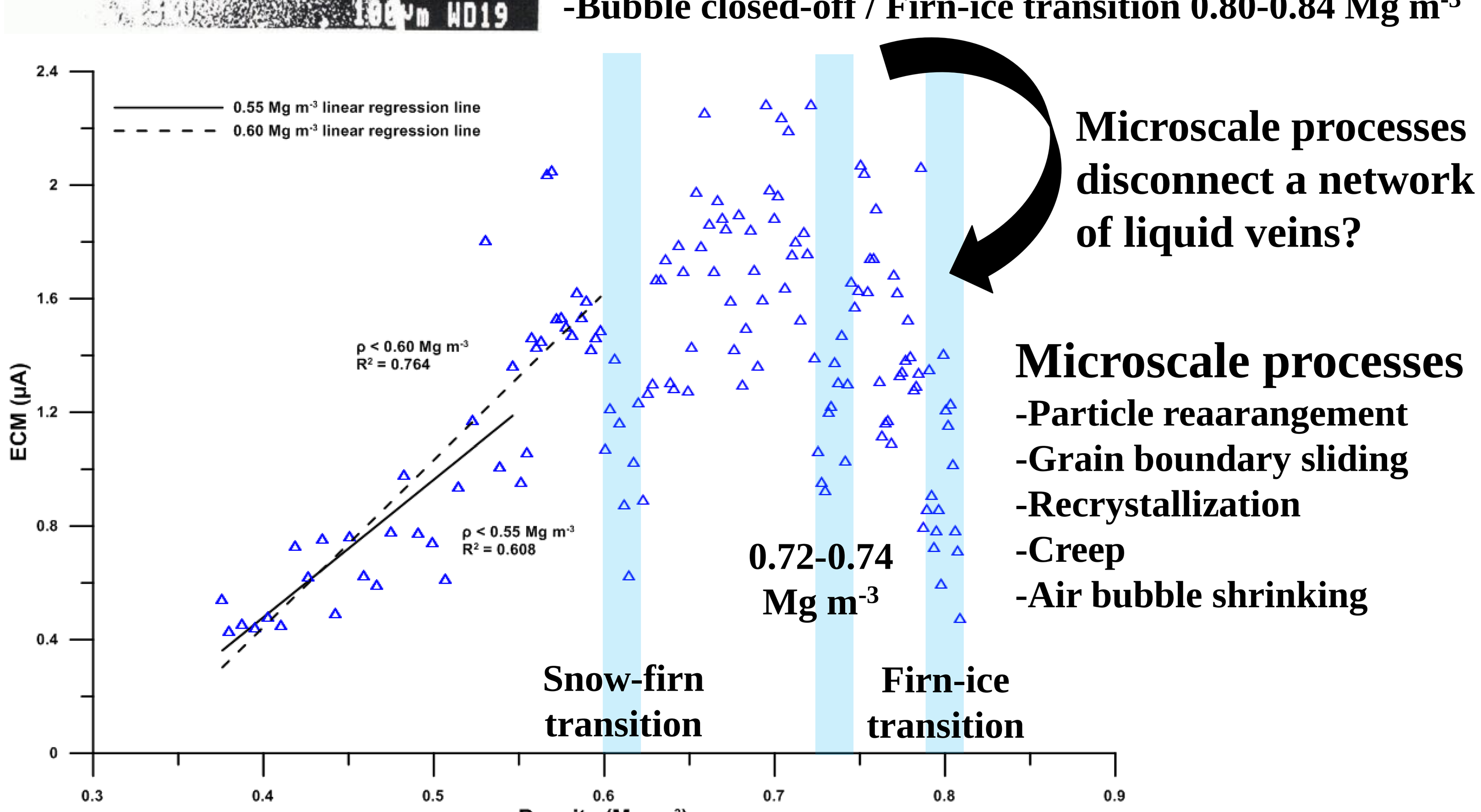


Fig. 7. Electrical Conductivity versus density for the whole core. Mean "critical" density values of 0.55, 0.73 and 0.82-0.84 Mg m^{-3} are often denoted for changes in the predominance of microscale processes(Hörhold et al., 2009).

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