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Looking Back at the Early Years of Pc 1 Pulsation Research

Geomagnetic pulsations—the ground-based signals of magnetospheric hydromagnetic waves—have been studied for well over 100 years. Some of the first observations were reported in 1861 by B. Stewart, who studied the recordings of the great magnetic storm of 1859. In Helsinki in the 1840s, J. J. Nervander observed magnetic "undulations" of constant period of about 30 s in his declination variometer.

At the turn of the century, more sensitive magnetic instruments and faster registration systems were developed and the basis was laid for the systematic classification of long period pulsations, which are now called Pc 3–Pc 5 and Pi 2 pulsations.

By the Second International Polar Year (SIPY), 1932–1933, only pulsations with a period in excess of about 20 s could be detected. Accordingly, the short period Pc 1 or Pc 2 pulsations had not been observed by then.

From August 1932 to August 1933, the SIPY observational program was carried out. At latitudes above 55°, 16 permanent and 24 temporary magnetic stations were in operation. Special quick-run magnetographs with a recording speed of 1 mm for 20 s were developed for the experiment and quick-run recorders of Earth currents were also used. Recordings were continued at some observatories even after the main SIPY program.

Early Method to Observe Pc 1s

As part of the SIPY effort, two papers that reported the first observations of Pc 1 geomagnetic pulsations were published in the same 1936 issue of one journal. Leiv Harang from the Auroral Observatory at Tromsø, Norway, and Eyvind Sucksdorff from the Geophysical Observatory at Sodankylä, Finland, analyzed rapid registrations made in Tromsø from 1932 to 1936 and in Sodankylä from 1932 to 1935, respectively.

Both authors noticed particularly formed and repetitive broadenings in the quick-run recordings, which they attributed to short-period oscillations (see Figure 1a). Sucksdorff described these broadenings as "characteristic and easily distinguishable widenings of the curve, the shape of which is often reminiscent of that of a short shuttle" and called them "rapid micropulsations" or "pearl necklace." Harang called them "vibrations."

The individual oscillations were too fast to be seen in the registrations, so it was impossible to determine the exact period of these new pulsations. However, both authors gave an estimate on the upper bound of the oscillation period. Harang's estimate was 1 s, Sucksdorff's 2–3 s. Thus both researchers realized that the oscillations were a new phenomenon, different from the longer period pulsations already known.

Both realized that the quick-run magnetometer system was able to record even a fairly feeble external forcing of the suspended magnet close to the magnet's eigenperiod, when the system is at a resonance. Harang pointed out that the new vibrations did not occur in the Eschenhagen variometer used for normal magnetic registrations and Sucksdorff noted that pearls appeared only accidentally in the vertical component due to its large moment of inertia. Neither researcher knew, however, the accurate values of the resonance properties of their systems.

In 1971, M. Kivinen determined the resonance properties of the second instrument used at Sodankylä from 1953 until 1983. He found the eigenperiods of the H, D and Z components to be 0.375, 0.480, and 0.333 Hz, respectively. Most interestingly, the amplification curves of all three components were very sharp. For example, the half width at half maximum for the H component was only 0.0038 Hz. The threshold field intensities for pulsations to be detected at the eigenperiod were 50, 60, and 140 pT for H, D, and Z components, respectively.

It is likely that the quick-run systems used by Harang and Sucksdorff had resonance properties similar to those of the instrument used by Kivinen. Kivinen's observation that the threshold intensity for the Z component was much higher than for other components agrees with Sucksdorff's note about the stiff vertical component of the equipment he was using. Of course, the accurate values of the eigenperiods may have been slightly different.

Taking into account the now well-known small frequency width of a typical Pc 1 band, the various elements with their unequal eigenfrequencies often registered different events. Sucksdorff observed this while analyzing the simultaneity of the rapid micropulsations in the various elements. Slightly less than half of the events were simultaneously observed in two or more elements, the magnetic H component following more closely the Earth currents.

Pc 1 Properties Observed

Sucksdorff aptly explained the essential features of the new pulsations: "Even a casual glance at the records reveals that rapid micropulsations occur in groups, and only from time to time. Usually they take place in the course of a few consecutive days, after which sometimes a week, or even a month, may pass before new oscillations occur." This is the basis for the later observation of the connection of pearl pulsations with the development of magnetospheric storms.

Both Harang and Sucksdorff studied the diurnal distributions of the new pulsations. Figure 2 depicts, in the respective local times, the diurnal distributions of Harang's observations and those of Sucksdorff's two magnetic components. Both authors established that the new pulsations at high latitudes were a daytime phenomenon. With the later observation of an early morning maximum at low latitudes, the diurnal distribution of Pc 1s remained unexplained. After it was realized that the average frequency and different morphological types of Pc 1 pulsations depend on latitude, this problem was resolved.

Harang's and Sucksdorff's observation of a daytime maximum stood the test of time. The difference of a couple of hours between their maxima is likely real and due to the different eigenfrequencies of the instruments, indicating that Harang's instrument had a higher eigenfrequency.

Sucksdorff compiled the hourly number of micropulsations for each month separately. Although he admitted that "the material at our disposal is too scanty for drawing a reliable conclusion," he noticed an annual change in the maximum of the diurnal distribution from prenoon in winter to afternoon in summer. Even today, this observation evades proper verification because of the large workload implied even with modern techniques. Both Harang and Sucksdorff also studied the annual distribution of Pc 1 s, concluding that the events maximize at the two equinoxes (Harang) or at the autumn equi-

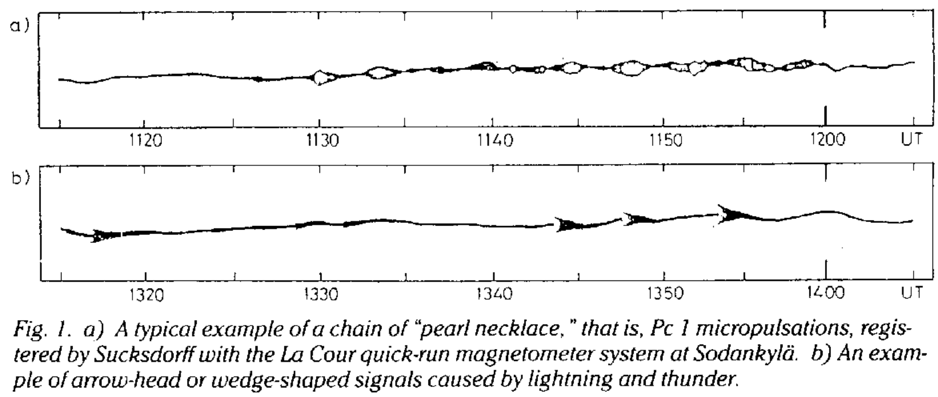

Fig. 1. a) A typical example of a chain of "pearl necklace," that is, Pc 1 micropulsations, registered by Sucksdorff with the La Cour quick-run magnetometer system at Sodankylä. b) An example of arrow-head or wedge-shaped signals caused by lightning and thunder.

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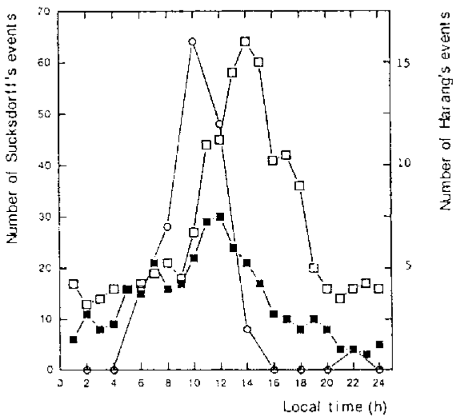

Fig. 2. The hourly number (on the left vertical axis) of Sucksdorff's micropulsation events in H component (open squares) and D component (solid squares) in 1932–1935, and of Harang's events in 1932–1936 (open dots; right vertical axis).

nox with a smaller maximum at the spring equinox and winter (Sucksdorff).

Sucksdorff also presents the total number of events each year for 1932–1935, but no particular variation was observed, because 1932–1934 was a period of very low sunspot number, marking the minimum between the solar cycles 16 and 17. The annual number of Pc 1 pulsations was later found to be in inverse correlation with sunspot numbers. In 1991, K. Mursala and colleagues used the registrations of the two systems at Sodankylä to establish this relation for nearly four solar cycles.

Harang and Sucksdorff compared their records with those obtained at other nearby stations. Because of the simultaneous occurrence of observations at the two sites, artificial disturbances could be excluded as their source. Sucksdorff also compared records from more remote stations, Copenhagen and Stockholm, allowing him to make observations about the more global features of Pc 1 pulsations. He concluded that while the detailed properties of micropulsations are local in character, their occurrence properties are similar. Furthermore, on occasion, these pulsations occur simultaneously over large distances, indicating that they have a common, and perhaps not very remote, source. On the basis of amplitude comparison, Harang also noted that the vibrations occur more pronouncedly near the auroral zone, another fact which was verified later.

No wonder that neither author could present a valid argument about the nature of the new short-period pulsations. Sucksdorff excluded lightning as a possible candidate, based on the odd, arrow-shaped form of the signal it produces (Figure 1b). Harang mentions seismicity as a possible source of vibrations, but excludes it as a general source because of the pronounced diurnal maximum he had observed. The hydromagnetic waves were theorized by Alfvén only a few years later in 1942, and the modern explanation for Harang's vibrations and Sucksdorff's micropulsations in terms of ion cyclotron waves was to come even later.

Despite the fundamental nature of the new and overwhelmingly correct observations made in these papers, they have remained fairly unknown to many pulsation researchers. Perhaps this is due in part to the peculiar data collection method used. Later, more modern methods were developed for studying short-period pulsations, but World War II cancelled many observations and studies, causing a gap of about 20 years in this research.

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