POLARIS: An In-depth Look at Canada's Subcontinental Mantle and Earthquake Hazards

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POLARIS (Portable Observatories for Lithospheric Analysis and Research Investigating Seismicity) is a multi-institutional $10M proposal to the Canadian Foundation for Innovation (CFI), for the creation of a network of portable, satellite-linked geophysical observatories. This proposal brings together universities, governments, and the private sector from across Canada in an innovative research project dedicated to interdisciplinary studies of subcontinental mantle architecture, earthquake hazards and related ground motion analysis in the northern half of the North American continent. Contributions made by LITHOPROBE have led to important advances on these fronts, but have also underscored the need for a fuller understanding of Earth structure and processes at a deeper, mantle level.

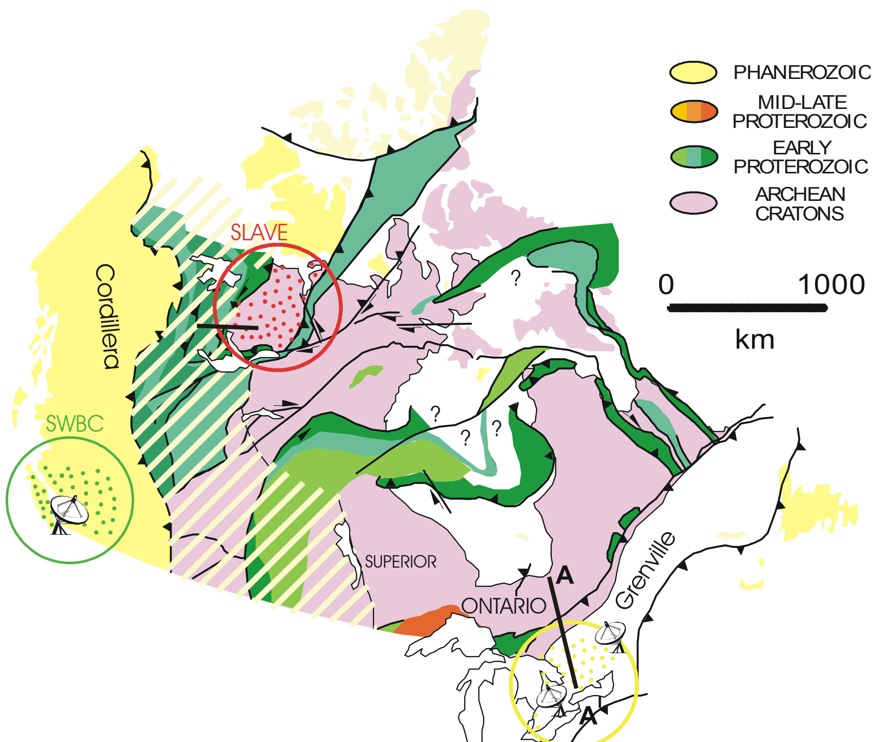

Figure 1. Map showing proposed locations of initial POLARIS arrays (circles enclosing dot patterns), superimposed on a tectonic map of Canada. Each array will contain 30 broadband seismometers, deployed for an initial period of 3-4 years. During this time, 30 MT instruments will provide another, transportable array to give equivalent regional coverage. Satellite dish symbols denote downlink facilities at Carleton University, the University of Western Ontario and the University of British Columbia.

The major components of POLARIS are a network of 90 three-component broadband seismometers, 30 magnetotelluric (MT) field systems, complementary data acquisition and satellite communications equipment, and three satellite downlink facilities. Over the initial four-year start-up phase of the project, the seismograph network will be deployed as three arrays of 30 instruments (**Figure 1**). The MT equipment will be used in shorter-term deployments at each of the three seismometer arrays for lithospheric imaging, and continuous recording at selected locations for deep-mantle imaging. POLARIS will be among the first mobile geophysical facilities in the world to exploit satellite communications technology for data acquisition (**Figure 2**). This new geophysical infrastructure will enable ground-breaking research in combined applications of co-located teleseismic and magnetotelluric arrays for lithospheric analysis. Data collected by this system will be available in near real-time over the Internet, and will be permanently archived by the Geological Survey of Canada.

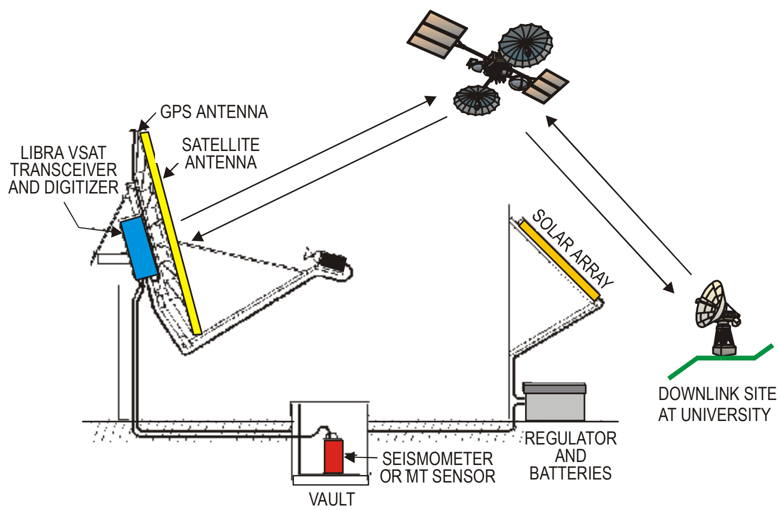

Figure 2. Cost-effective, real-time access to remote POLARIS geophysical observatories will be achieved using a very small aperture terminal (VSAT) satellite telemetry system. Downlink sites at Carleton University, the University of Western Ontario and the University of British Columbia will provide access to the data via the Internet.

In its initial phase, POLARIS research will focus on projects developed around three separate arrays of instruments. One array, deployed in the NWT/Nunavut, will be used to investigate lithospheric roots and asthenospheric mantle underlying the Slave craton in Canada's north. Reconnaissance teleseismic and MT surveys have already yielded tantalizing information about the fine structure and evolution of the mantle root beneath the craton [Bostock 1998] (**Figure 3a**), as well as structural complexity in the upper mantle beneath diamond-producing kimberlite fields. New research will afford a view of the subcontinental root in unprecedented detail, and will provide Canada's fledgling diamond industry with critical information on the mantle environment that spawns kimberlite magmas and enables their rapid ascent to the surface.

A second POLARIS project will investigate the seismic risk to southern Ontario, an issue of great social and economic importance due to the density of population and critical facilities (such as nuclear power plants). Earthquake risk in Ontario has received much public attention, with different sources citing differing views on the level of hazard [Adams et al. 1993; Mohajer et al. 1993]. Recent earthquakes, such as the November 26, 1999 earthquake (MN = 3.9) beneath Lake Ontario near Toronto, and the January 1, 2000 earthquake (MN=5.2) near North Bay have contributed to renewed public concern. POLARIS studies will provide dense

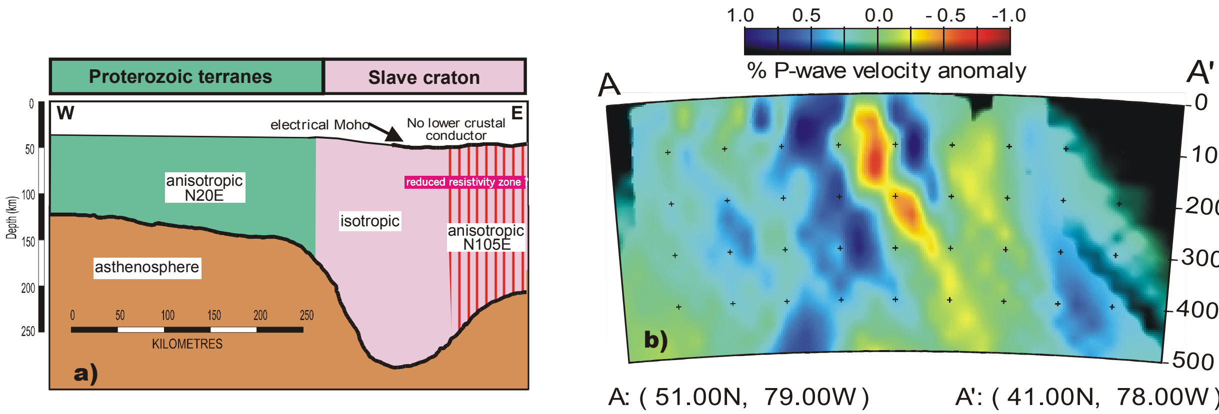

Figure 3. Examples of lithospheric imaging capabilities of POLARIS. a) Lithospheric cross-section showing variations in strength and direction (anisotropy) of conductivity used to map the boundary between the lithosphere and underlying, partly molten asthenosphere. See Figure 2 for location in NW Canada (black line). b) Depth profile in Ontario and Québec, as determined from inversion of teleseismic P-wave traveltime residuals. Areas in red and blue represent mantle through which P-waves travel more slowly and more rapidly than average, respectively. Areas in black are regions which were not sampled by waves. The narrow region of low velocity (red) extending to ~300 km depth near 46N is interpreted to be the signature of the 130 Ma Great Meteor hotspot track.

instrumentation in southern and central Ontario, facilitating investigations of the potential severity of earthquake shaking, the effects of local site conditions, and the geometry and distribution of potentially important faults. Three-dimensional techniques will also be used to image the lithosphere of the Grenville Province (see **Figure 3b**), potentially yielding new insights about the role of the mantle in continental growth and collisional orogenesis.

The third POLARIS deployment will be used for mapping the structure and earthquake hazards over the Cascadia subduction zone in southwest British Columbia. This vital economic region, home to nearly 2 million people and a vast supporting infrastructure, is at risk from three distinct source zones: i) rare, but extremely large (M>9) megathrust earthquakes; ii) deep earthquakes within the subducting oceanic plate; and iii) shallow, crustal earthquakes within the North American plate. POLARIS infrastructure will be used to map variations in ground shaking due to site response, and to develop region-specific ground motion relations. In addition, continuous monitoring of the low-frequency MT field at specific locations will facilitate analysis of time-varying conductivity structure of the Earth in response to earthquake processes.

International co-ordination and partnerships are an explicit and essential component of the POLARIS project. For example, USArray [Levander et al. 1999] is a major proposed facility that will include 500-1000 portable broadband seismographs, dedicated to mapping the lithosphere and upper mantle at a uniform scale throughout the continental United States. POLARIS infrastructure will provide a vehicle for co-ordinated, collaborative study with the American effort and permit extension of USArray throughout the majority of the continent. NEPTUNE is a joint US/Canadian initiative to instrument the subducting Juan de Fuca plate with 20-40 unmanned seafloor observatories. Integration of POLARIS and NEPTUNE arrays will provide very high resolution imaging of the subducting plate and earthquake rupture processes in both the onshore and offshore regions. Finally, sharing of data and expertise with the U.S. based COSMOS (Consortium of Organizations for Strong Motion Observation Systems) will provide the basis for fruitful collaborations between engineers and seismologists to further our public safety objectives.

Looking beyond the initial five-year start-up phase of the project, the POLARIS infrastructure will provide an important legacy for continued research by Canadian and international scientists. As a national facility, POLARIS infrastructure will be made available to investigators on the basis of merit of their research proposals. Operational procedures used for similar facilities in other countries (e.g., IRIS-PASSCAL) may serve as a useful guide in this respect. Scientific and operational aspects of the facility will be managed by a national steering committee, with membership from universities, the GSC and industry. One responsibility of the steering committee will be the organization of annual scientific workshops to provide training and foster rapid communication of new results. Planned research initiatives include the development and testing of rapid warning systems for ground shaking in the urban areas of Canada; development of new high-resolution imaging techniques using the scattered wavefield; and investigation of geomagnetically induced currents (GIC's) that can cause major disruptions to electrical and pipeline infrastructure.

References

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