

From Crust to Core: EarthScope comes to Yukon

What is EarthScope?

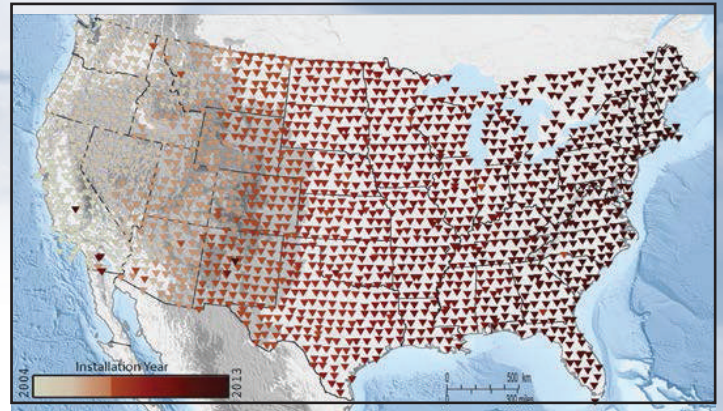
The United States National Science Foundation (NSF) has provided funding for a large collaborative research project known as EarthScope. The purpose is to study the North American continent by deploying seismic (earthquake) sensors through the USArray program and GPS instruments through the Plate Boundary Observatory (PBO).

Since 2003, USArray has installed temporary networks of seismometers known as the Transportable Array (TA) across the contiguous United States (the lower 48 states), and in southern Ontario and Quebec. The TA consists of 400 high-quality, portable seismic stations that are placed at temporary sites. Unless adopted and made into a permanent installation, each USArray instrument is picked up and moved after 18 to 24 months to the next carefully spaced array location. When completed, more than 2,000 locations will have been occupied during the USArray program. The earthquake data gathered from these sites result in more accurate maps of earthquake locations and are analyzed to produce high-resolution images of Earth's interior. All data are freely accessible from EarthScope.

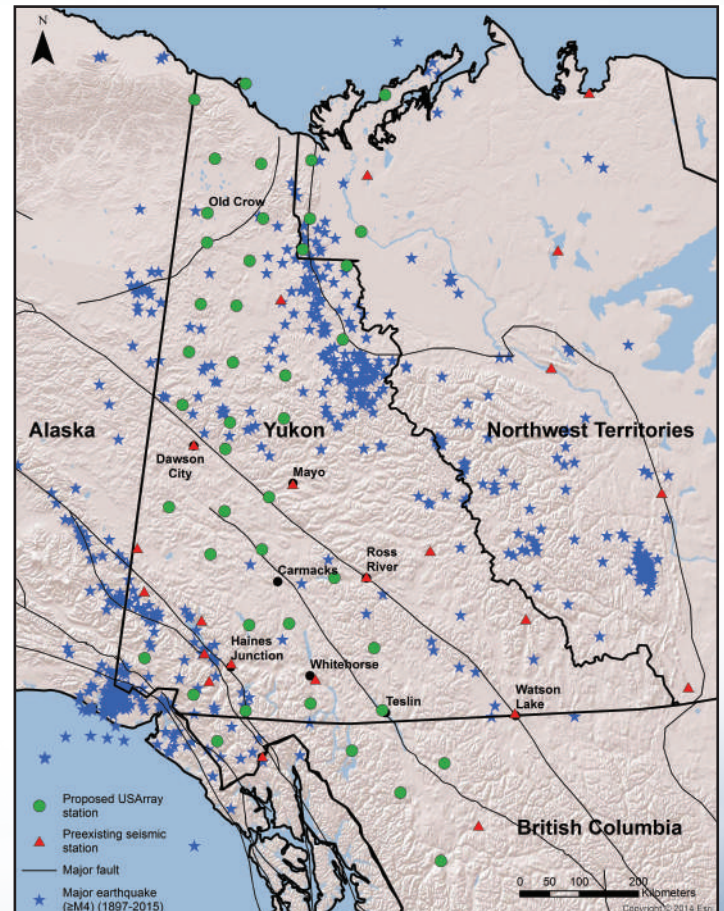
What is EarthScope's plan for Yukon?

In 2013 and 2014, USArray installed a total of 25 stations in Alaska. Beginning in 2015, USArray is proposing to place temporary seismic stations at approximately 32 locations across the Yukon, five in western Northwest Territories, and six in northern British Columbia. It will take three years (2015-2017) to achieve full deployment. When complete, the total number of USArray TA stations in Alaska and northwestern Canada will reach approximately 300. In addition to generating 3-D images of the earth from the crust to the outer core (2880 km depth), these installations will enable scientists to increase the accuracy of earthquake locations in the North and to gain insight into earthquake processes.

The USArray stations deployed in northwestern Canada will supplement existing seismic stations operated by Natural Resources Canada's national and regional networks (15 sites) and by the University of Ottawa's Yukon Northwest Seismic Network (nine sites). Additional research projects will take advantage of this infrastructure to support targeted studies in northwestern Canada and Alaska.



The map above shows the locations of the Transportable Array seismometers that were installed between 2004 and 2013. Most were removed and re-located as the array progressed from west to east.



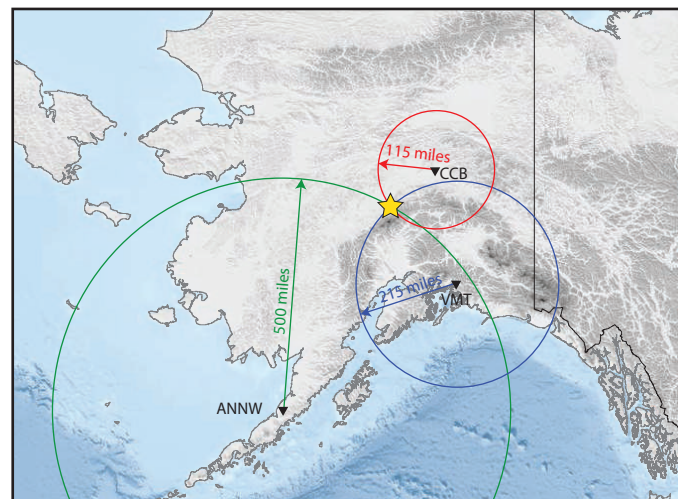
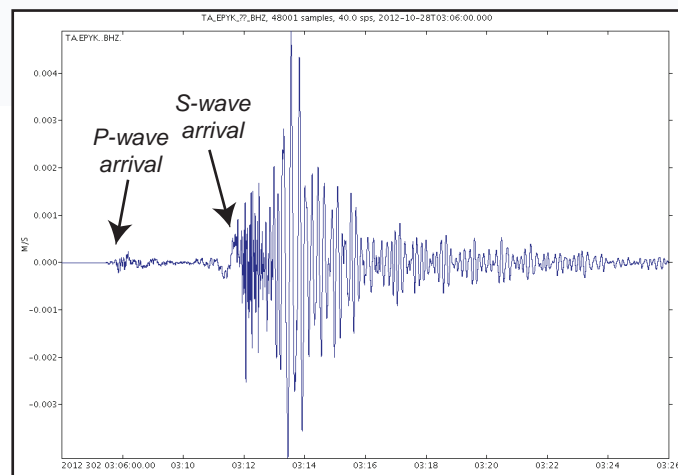
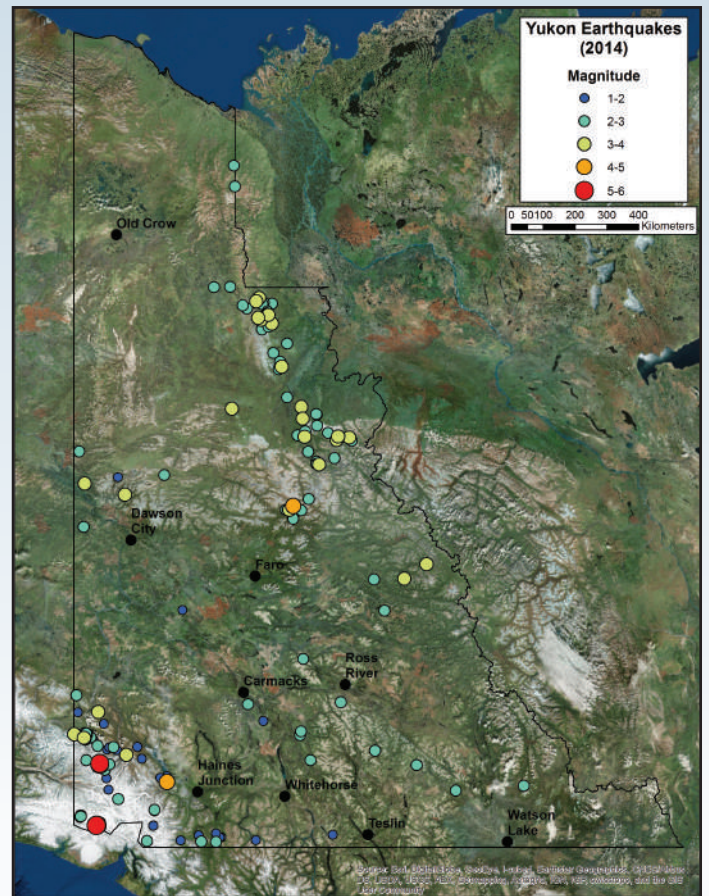
The map above shows the location of existing seismic stations in Yukon and NWT (red triangles), as well as proposed USArray seismic station locations (green circles). Major (\geq magnitude 4) earthquakes dating back to 1897 are indicated by blue stars.

Yukon earthquakes

There were 195 recorded earthquakes in Yukon in 2014. Most earthquakes go unnoticed, but occasionally larger events are felt. Since 1985, 4151 earthquakes have occurred within the Yukon, 17 with magnitudes greater than 5.0. The largest Yukon earthquake in the past 30 years occurred on July 17th, 2014, and was a magnitude 5.9 event with an epicenter located 335 km west of Haines Junction. The largest recorded earthquake in Yukon was in 1899, when a magnitude 8.0 earthquake along the Yukon-Alaska border triggered landslides and a tsunami, and caused considerable damage.

Seismic stations in Yukon also record earthquakes from around the world, including recent great earthquakes in Japan and Chile as well as earthquake activity along faults in Alaska and Yukon, e.g. the Denali and Duke River faults and the Richardson fault array in northern Yukon. Earthquakes in Alaska and British Columbia are often felt by residents in Yukon.

Right: Map of earthquakes occurring in 2014 with epicenters within Yukon. Symbols represent the magnitude of each event.



Determining the location of earthquakes

Two waves of energy are released when an earthquake occurs - P or "primary" waves, and S or "secondary" waves. These waves travel at different speeds and thus arrive at a seismic station at different times. The time difference between the two arrivals (S-P) can be measured with a seismometer.

Seismologists have defined the relationship between a difference in S-P arrival times and the true distance between an earthquake epicenter and a station recording the event. Once this distance is calculated for three stations, the earthquake's epicenter can be located. A circle centered on each station is drawn with the circle's radius equal to the distance the station is from the earthquake. The point where all three circles intersect is the location of the earthquake's epicenter.

If four or more stations are used, a depth (the focus) of the earthquake can be calculated. Seismologists use computers to get the most accurate earthquake location possible by analyzing data from all stations that recorded the earthquake.

Left top: Waveform data from 2012 Haida Gwaii earthquake (M7.8) recorded at the Eagle Plains seismic station.

Left bottom: Example of the use of three seismic stations to determine the epicenter of an Alaskan earthquake.

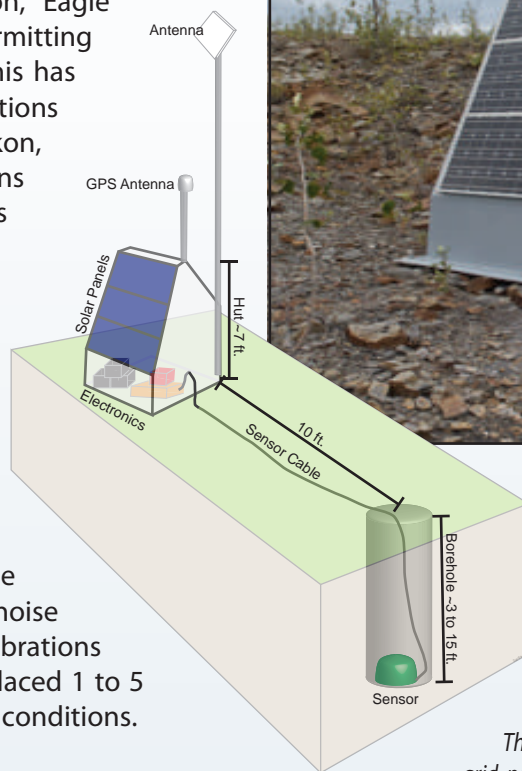
How will installation take place in Yukon?

The vast, complex terrain of the Yukon makes the installation of seismic stations challenging. The lack of roads throughout most of the Yukon is an obstacle, and some remote installations will be helicopter-supported. Site installations will be managed from a number of logistical hubs within Yukon and NWT (Whitehorse, Haines Junction, Eagle Plains, Carmacks, Dawson City and Inuvik). Permitting and consultation for USArray began in 2012. This has included discussions, meetings and consultations within the science permitting protocols in Yukon, NWT, and BC; as well as preliminary discussions with YESAB, First Nations, and other stakeholders including Parks Canada. These consultations are still ongoing.

What is a Transportable Array (TA) seismic station?

The heart of the Transportable Array station is the seismic sensor, an instrument capable of detecting minute vibrations in the earth. Transportable Array stations do not create noise or motion. To reduce interference from surface vibrations and to protect the sensor, the seismometer is placed 1 to 5 meters below the surface, depending on ground conditions.

A fiberglass enclosure fitted with solar panels is placed about 3 meters from the sensor. The enclosure houses batteries and communications electronics. Data are transmitted through cellular, broadband, or satellite communications systems to the EarthScope/IRIS data center in real-time using satellite or internet communication technology. The overall footprint of the station is about 3 meters by 7 meters.



USArray photo

The photo and diagram illustrate the seismic station design being implemented in Alaska and Yukon. The station is powered by solar energy or grid power, and seismic and meteorological data are transferred to the EarthScope/IRIS data center in real-time using satellite or internet communication technology. The electronics hut at the Eagle Plains station is pictured above.

How is a TA seismic station installed and does it require maintenance?

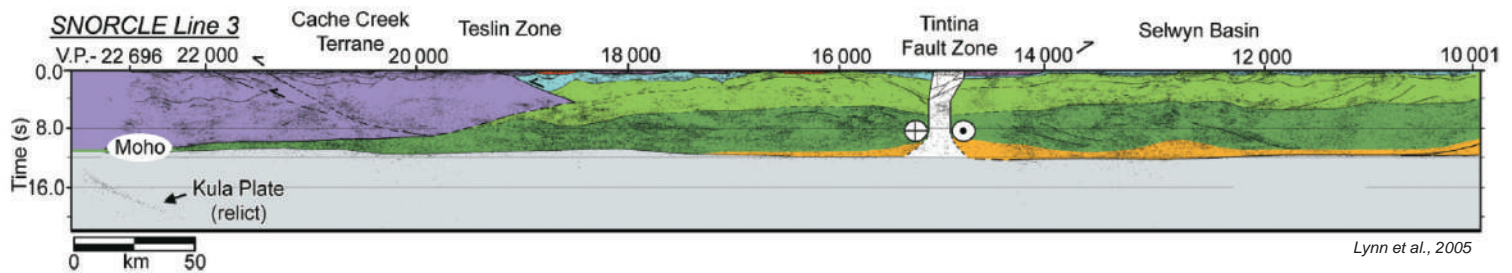
The installation of a Transportable Array seismic station takes one to two days. Some locations may require helicopters to sling equipment into position to minimize ground disturbance. The seismometer and other equipment operate continuously and are monitored remotely. If the station malfunctions, it is identified at the data center and a service trip may be necessary to correct the problem.

Installation will adhere to permitting and environmental regulations, as well as respect concerns raised during the consultation process to ensure minimum impact on traditional use of lands.

Installation of the seismic sensor at Eagle Plains station (EPYK)



USArray photo



An example of a regional seismic interpretation in the Yukon from the earlier Lithoprobe project. This interpretation shows the subsurface boundaries between individual terranes, as well as the crust (purple-orange-green) - mantle (grey) boundary at ~30 km depth.

Why is Yukon of interest to EarthScope?

The geology of Yukon and northwestern Canada reflects a complex history of plate tectonic interactions between crustal blocks (terrane) that have collided with the western margin of ancestral North America. The interaction between these blocks helped lead to the formation of the mountains of the Canadian Cordillera, and active crustal deformation continues to the present day.

The seismicity of Yukon is dominated by events occurring along the Denali, Duke River, Border Ranges and Columbus fault systems in southwestern Yukon. These faults are driven by the northward movement of the Pacific Plate sliding past the North American Plate on which Yukon resides. Further inland, the seismicity recorded in active areas such as the Richardson and Wernecke Mountains, while linked to the same stresses as the Pacific-North American plate margin, is also strongly influenced by the Beaufort Sea convergent margin between the Canning River seismic zone in Alaska and the Eskimo Lakes-Richardson Mountain seismic zone to the east in Yukon and NWT.

The USArray seismic array is designed to specifically target large-scale structures of the earth down to the mantle-outer core boundary, approximately 2880 km below the earth's surface. Although the TA will greatly improve the definition of seismically active faults, its wide spacing precludes detailed resolution of geological features in the shallow crust, and is therefore of little use in mineral and petroleum exploration. Regional seismic data is better oriented to provide baseline geological and geophysical information about an area.

Where can I find more information about EarthScope and earthquakes?

USArray Website:

<http://www.usarray.org>

View signals at your closest station:

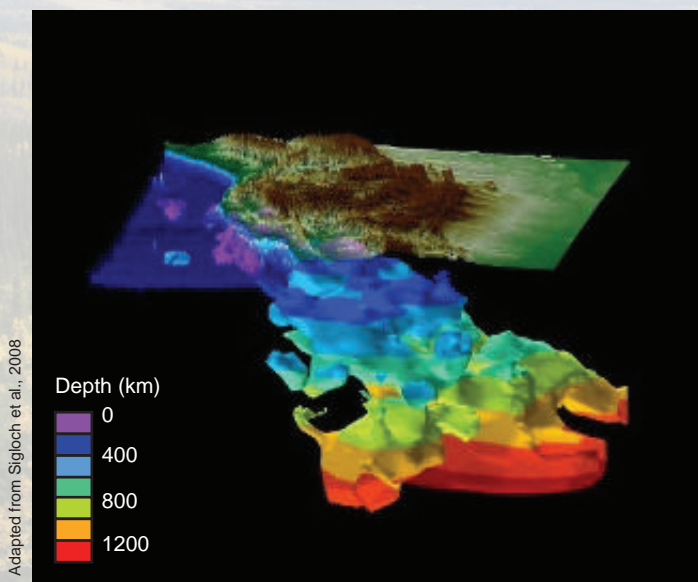
<http://usarray.seis.sc.edu>

Incorporated Research Institutions for Seismology (IRIS):

<http://www.iris.edu>

Earthquakes Canada, Natural Resources Canada

<http://www.earthquakescanada.nrcan.gc.ca>



Seismic tomography image from USArray data of the Farallon oceanic plate subducting to depths of 1,800 km under the western United States. Researchers hope to develop similar imaging for plate interactions in Alaska and Yukon.

Project Partners



Yukon College



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