Controlled Source Experiments at the Sanford Underground Research Facility: Probing Anisotropy at Multiple Scales

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Abstract
Write later when the paper is further along

Introduction

Introduction figure – needs a base map to show general location and refer to 3D pdf that will be in supplement. Have not been able to figure out how to insert a 3D pdf into a word file.

Underground nine-component surveys

Nine-component (9C) surveys (references) were developed in the oil and gas industry to improve imaging of the subsurface with shear wave data and to provide observational data to better understand anisotropy of sedimentary rocks. The name comes from the nine combinations of data possible with three-component sensor used to record a source polarized in three orthogonal directions. We conducted nine-component surveys at SURF in three different locations seen in Figure 1 with details shown in Figure 2.

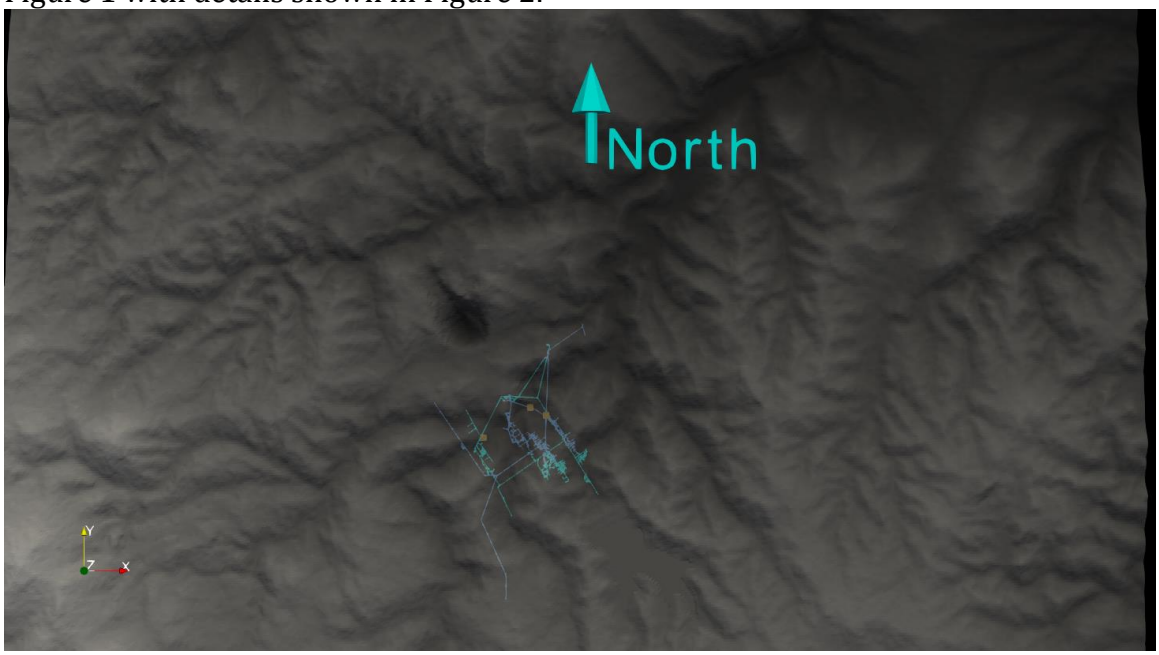

Figure 1. Prototype figure for basemap. Need something better than this placeholder. Needs a multifaceted map.

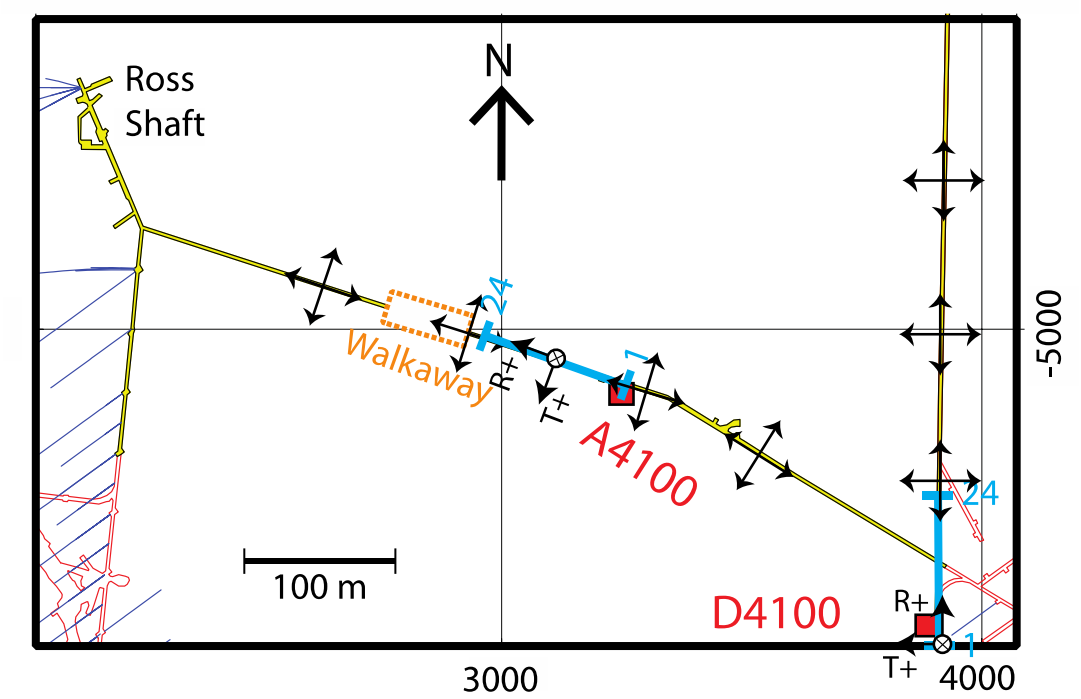

Figure 2a. Map of geometry of underground three-component surveys on 4100 ft level.

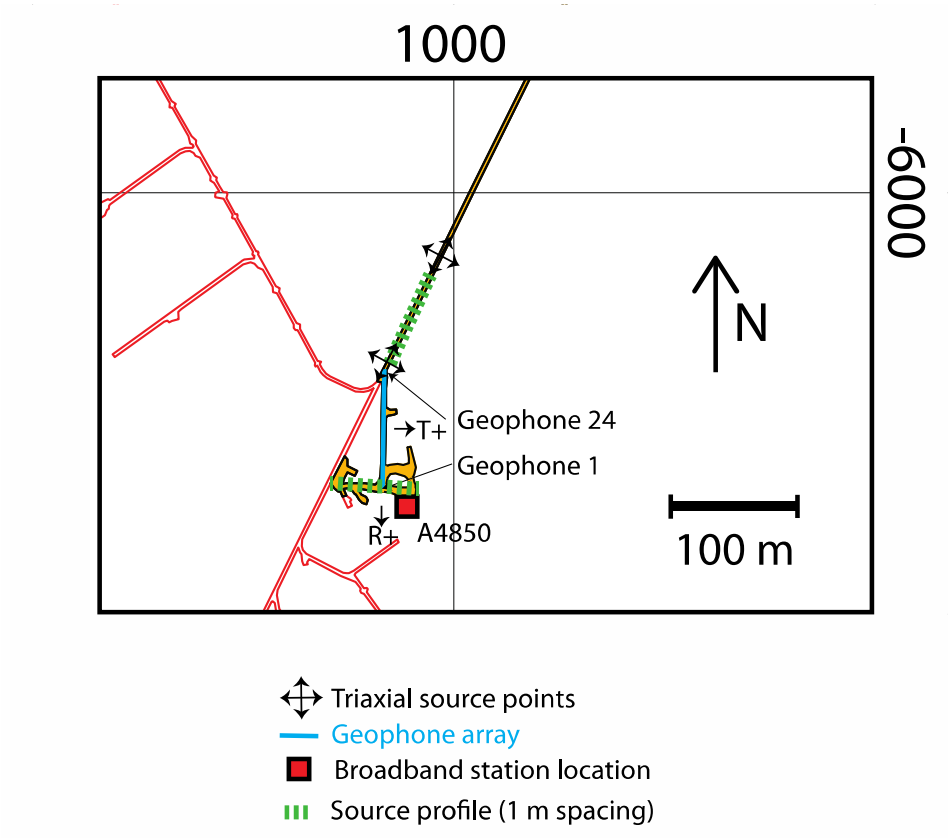

Figure 2b. Geometry of underground three-compoentn surveys on 4850 ft level.

Conducting a nine-component survey in a mine drift presented some practical challenges. Because we hope future similar experiments will be conducted at SURF or other underground facilities these lessons are an important contribution of this paper. However, since those issues are only indirectly important to the scientific element so this paper we put that material the electronic supplement.

The first 9C experiment we conducted is the one show in Figure 2a with the label 4100A. Those data are the poorest quality for two reasons. First, we refined most of our procedures during that experiment including sensor anchoring procedures, alignment procedures, and the methods for shooting (see supplement). Second, that area had the poorest site conditions of the three 9C experiments. The drift floor on the north end of the sensor array was wet and muddy making anchoring the sensors exceptionally challenging.

All three 9C surveys utilized 5 shot points per source point: T+ and T- (transverse to drift direction), R+ and R- (aligned with drift direction), and Z (vertical force down). For 4100A we used this combination at 4, 96, and 192 m offsets. The data with 192 m offset had very weak signals with the source we used so we dropped the 192 m offset series for 4100B and the experiment on 4850 (Figure 2b). The + and – polarity for R and T sources were executed hoping to use the technique commonly used in shallow vertical seismic profile (VSP) experiments described by REFERENCE. In surface VSP experiments it is common to superimpose the seismograms with alternate polarity to distinguish the S arrival from P reverberations. We found that approach did not work for the source we used and the simple method we used to couple the source to the rock. This is illustrated most effectively with the layered PDF example found in the electronic supplement to this paper.

Working Figures for reference for February 2018 teleconference

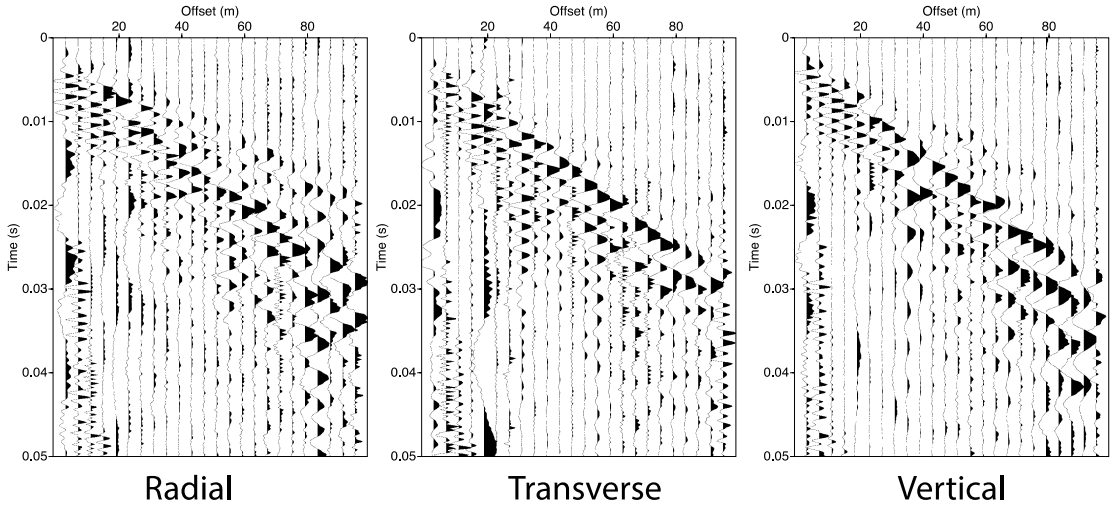

Figure 3. Example shot gather

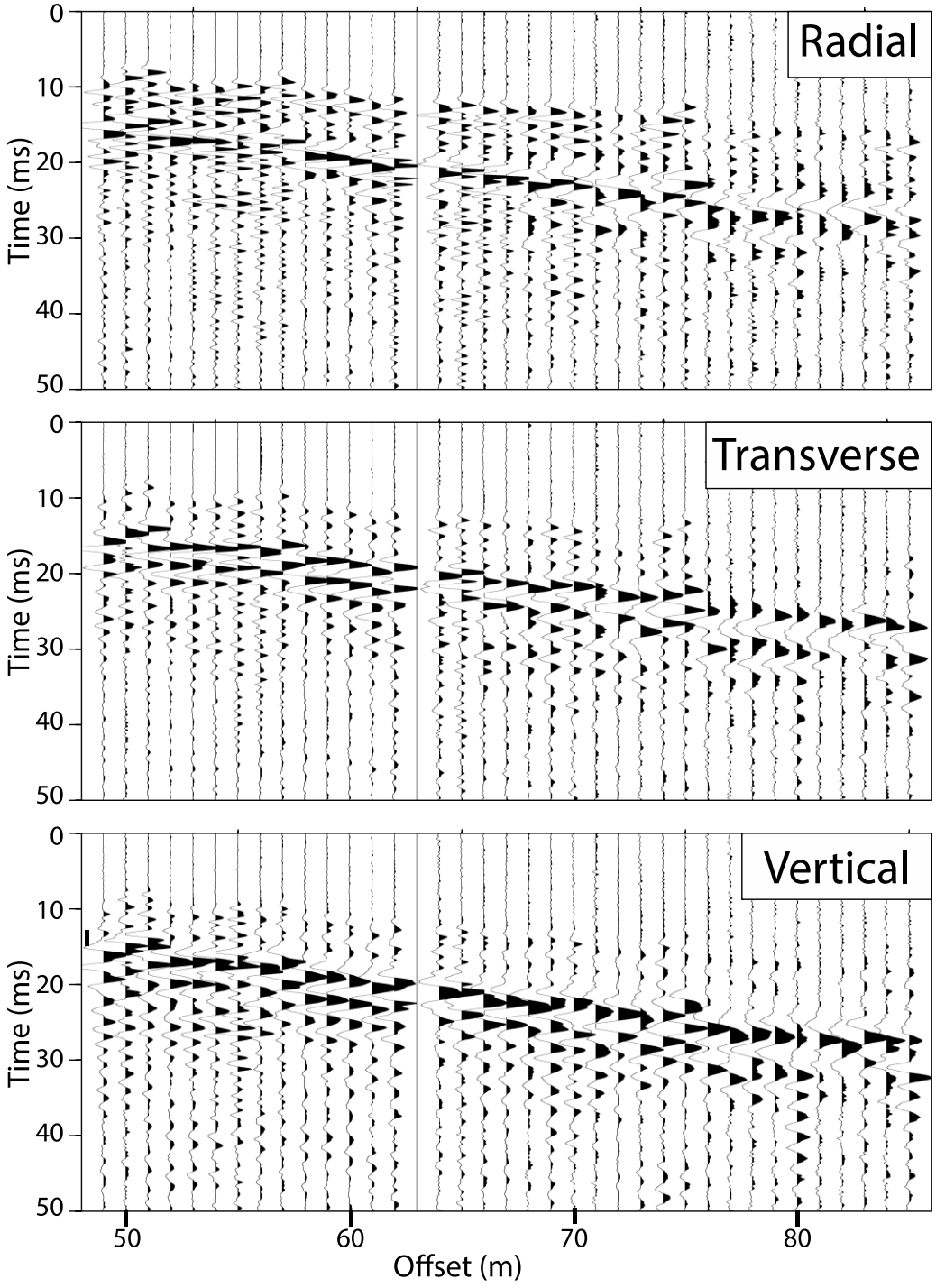

Figure 4. Example common receiver gather

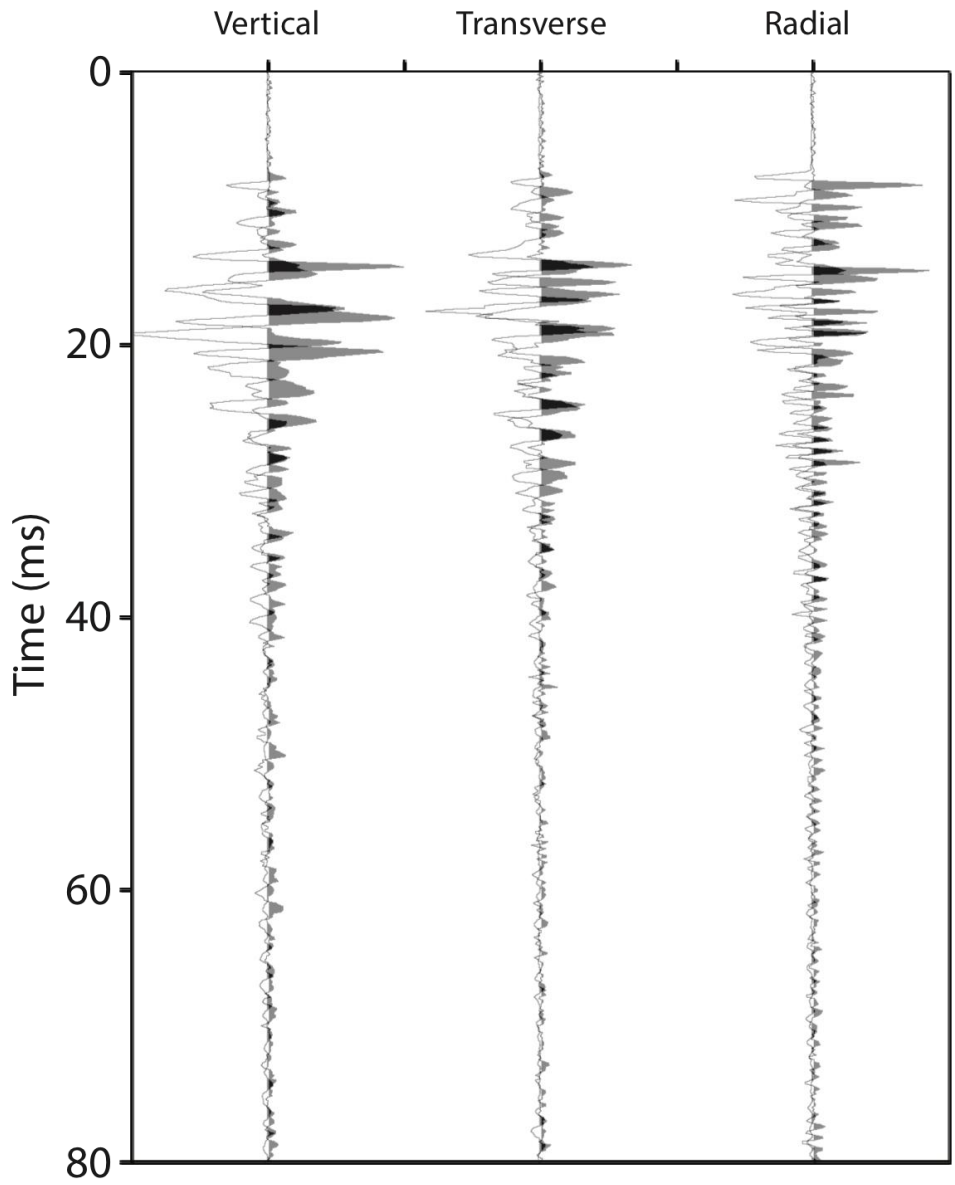

Figure 5. Overlay of seismograms collected with tranverse force on alternate sides of mine drift.

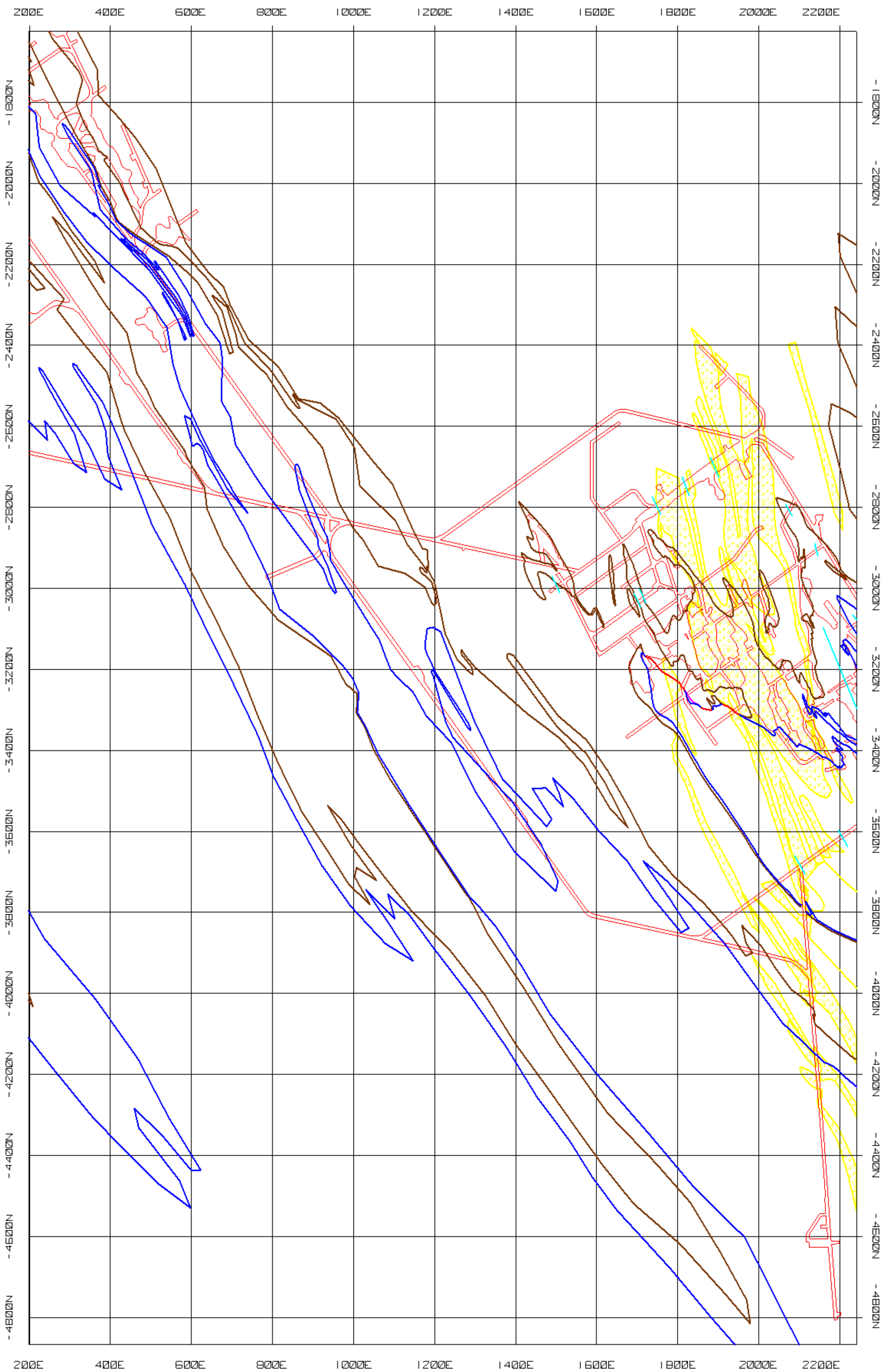
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Figure 6. Geology base map foro 2000. Needs editing to show location of 2000 survey