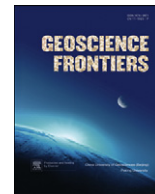


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Review paper

History and evaluation of national-scale geochemical data sets for the United States

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ABSTRACT

Six national-scale, or near national-scale, geochemical data sets for soils or stream sediments exist for the United States. The earliest of these, here termed the 'Shacklette' data set, was generated by a U.S. Geological Survey (USGS) project conducted from 1961 to 1975. This project used soil collected from a depth of about 20 cm as the sampling medium at 1323 sites throughout the conterminous U.S. The National Uranium Resource Evaluation Hydrogeochemical and Stream Sediment Reconnaissance (NURE-HSSR) Program of the U.S. Department of Energy was conducted from 1975 to 1984 and collected either stream sediments, lake sediments, or soils at more than 378,000 sites in both the conterminous U.S. and Alaska. The sampled area represented about 65% of the nation. The Natural Resources Conservation Service (NRCS), from 1978 to 1982, collected samples from multiple soil horizons at sites within the major crop-growing regions of the conterminous U.S. This data set contains analyses of more than 3000 samples. The National Geochemical Survey, a USGS project conducted from 1997 to 2009, used a subset of the NURE-HSSR archival samples as its starting point and then collected primarily stream sediments, with occasional soils, in the parts of the U.S. not covered by the NURE-HSSR Program. This data set contains chemical analyses for more than 70,000 samples. The USGS, in collaboration with the Mexican Geological Survey and the Geological Survey of Canada, initiated soil sampling for the North American Soil Geochemical Landscapes Project in 2007. Sampling of three horizons or depths at more than 4800 sites in the U.S. was completed in 2010, and chemical analyses are currently ongoing. The NRCS initiated a project in the 1990s to analyze the various soil horizons from selected pedons throughout the U.S. This data set currently contains data from more than 1400 sites. This paper (1) discusses each data set in terms of its purpose, sample collection protocols, and analytical methods; and (2) evaluates each data set in terms of its appropriateness as a national-scale geochemical database and its usefulness for national-scale geochemical mapping.

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1. Introduction

V.M. Goldschmidt, generally considered to be the father of modern-day geochemistry, stated that the primary purpose of geochemistry is to determine quantitatively the chemical composition of the Earth and its parts, and to discover the laws that

control the distribution of the individual elements (Goldschmidt, 1937, 1954). Understanding the abundance and distribution of the chemical elements in the near-surface environment of the Earth is critical for such fields as risk-based assessment of contaminated land, agriculture, animal and human health, water quality, land-use planning, mineral exploration, industrial pollution, and environmental regulation. The first national-scale geochemical surveys to address these issues began in the 1960s and expanded in number during the latter part of the twentieth century (Garrett et al., 2008). These studies resulted in a number of geochemical databases and atlases for entire countries or, in some cases, multiple countries (e.g., Webb et al., 1978; Fauth et al., 1985; Thalmann et al., 1989; McGrath and Loveland, 1992; Lahermo et al., 1996; Kadūnas et al., 1999; Ottesen et al., 2000; Reimann et al., 2003; Imai et al., 2004; Salminen et al., 2005; De Vos et al., 2006).

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To qualify as a true national-scale geochemical data set, several criteria should be met:

- Relatively uniform sample coverage of the entire nation;
- A sample density sufficient to allow robust estimates of element abundance and spatial distribution. For a large country the size of the conterminous U.S., about 1000 sites would be considered the minimum necessary;
- Consistent sample medium, or media, collected at each site;
- State-of-the-art analytical protocols with detection limits below crustal abundance concentrations.

Over the past 50 years, there have been six geochemical studies conducted in the United States (U.S.) that focused on element distribution in stream sediments or soils and meet at least some of the criteria above for a national-scale geochemical survey. The purpose of this paper is to: (1) provide a brief review of each of these studies in terms of purpose, sampling protocols, and analytical methods; and (2) evaluate the strengths and weaknesses of each generated data set in terms of its appropriateness as a national-scale geochemical database and its usefulness for national-scale geochemical mapping.

2. USGS ‘Shacklette’ database for soils

2.1. Background and purpose

The first effort to produce a national-scale geochemical database for the U.S. was conducted by the U.S. Geological Survey (USGS) from 1961 through 1975 using soil as the sampling medium (Boerngen and Shacklette, 1981; Shacklette and Boerngen, 1984; Gustavsson et al., 2001). The project, which focused only on the conterminous U.S. (7.9 million km²), was conceived and coordinated by H.T. Shacklette, a research botanist with the USGS. The

stated purpose of the project was to obtain estimates of the range of element concentrations in soils that were unaltered, or very little altered, from their natural condition (Shacklette and Boerngen, 1984). For this reason, this data set is considered to represent the background range for elements in soils of the conterminous U.S.

2.2. Sampling and analytical protocols

Sampling was conducted by USGS personnel at sites located along their routes of travel to project areas and within project areas in various parts of the U.S. The location of the sites, therefore, depended on both the road network and the destination of the samplers. In general, sampling sites were selected at 80-km intervals along the roads. Samples were collected at a total of 1323 sites, representing a density of approximately 1 site per 6000 km², between 1961 and 1975 (Fig. 1). Phase 1 of the study was conducted between 1961 and 1971 and resulted in the collection of 863 samples. The remaining samples were collected between 1971 and 1975 with sites chosen to complete more uniform sample coverage of the conterminous U.S. Because so many different people were involved in the sampling and because the collection of these samples was incidental to the other duties of the samplers, Shacklette kept the sampling protocol as simple as possible. He requested that, if possible, the samples should be collected from sites sustaining native vegetation. In some areas, however, only cultivated fields were available for sampling. The sampling protocol called for collection of soil samples from a depth of approximately 20 cm to minimize the effects of surface contamination, if present. Most of the samples represented true “soils” in that they were a mixture of weathered rock or unconsolidated parent material and organic matter and they supported plant growth. However, a few of the samples represented other regoliths such as sand dunes, loess, and beach deposits containing no visible organic matter.

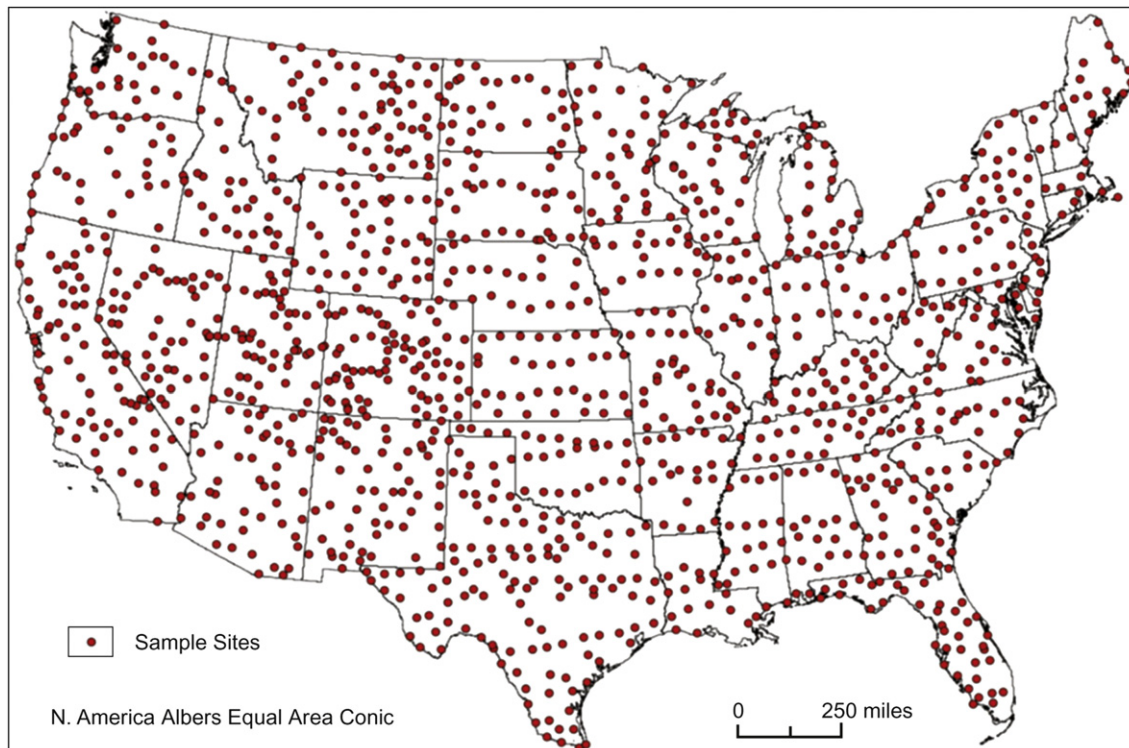


Figure 1. Location of 1323 soil samples collected by USGS from 1961 to 1975 (Boerngen and Shacklette, 1981; Shacklette and Boerngen, 1984).

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