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The distribution of selected elements and minerals in soil of the conterminous United States

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ABSTRACT

In 2007, the U.S. Geological Survey initiated a low-density (1 site per 1600 km^2, 4857 sites) geochemical and mineralogical survey of soil of the conterminous United States as part of the North American Soil Geochemical Landscapes Project. Three soil samples were collected, if possible, from each site; (1) a sample from a depth of 0 to 5 cm, (2) a composite of the soil A-horizon, and (3) a deeper sample from the soil C-horizon or, if the top of the C-horizon was at a depth greater than 100 cm, from a depth of approximately 80–100 cm. The <2 mm fraction of each sample was analysed for a suite of 45 major and trace elements following near-total multi-acid digestion. The major mineralogical components in samples from the soil A- and C-horizons were determined by a quantitative X-ray diffraction method using Rietveld refinement. Sampling ended in 2010 and chemical and mineralogical analyses were completed in May 2013. Maps of the conterminous United States showing predicted element and mineral concentrations were interpolated from actual soil data for each soil sample type by an inverse distance weighted (IDW) technique using ArcGIS software. Regional- and national-scale map patterns for selected elements and minerals apparent in interpolated maps are described here in the context of soil-forming factors and possible human inputs. These patterns can be related to (1) soil parent materials, for example, in the distribution of quartz, (2) climate impacts, for example, in the distribution of feldspar and kaolinite, (3) soil age, for example, in the distribution of carbonate in young glacial deposits, and (4) possible anthropogenic loading of phosphorus (P) and lead (Pb) to surface soil. This new geochemical and mineralogical data set for the conterminous United States represents a major step forward from prior national-scale soil geochemistry data and provides a robust soil data framework for the United States now and into the future.

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1. Introduction

Soil is at the junction of the lithosphere, the biosphere, and the atmosphere, and has a critical role in all aspects of ecology and human existence. Soil supports food production, controls water storage and ground water recharge, and shapes the biogeochemical cycles for essential nutrients in the environment. Despite the vital status of soil, there has been a remarkable lack of information on soil geochemistry for soil collected and analysed with consistent protocols for much of the North American continent (Smith et al., 2013a). These data limitations were addressed by the North American Soil Geochemical Landscapes Project (NASGLP), a cooperative project among the national geological surveys of the United States, Mexico, and Canada (Friske et al., 2013; Smith et al., 2009, 2011, 2012). The objectives of the NASGLP were to (1) produce a soil geochemical and mineralogical database, and its representation in map form, for the continent of North America (21 million square kilometres), (2) interpret observed geochemical and mineralogical patterns in terms of processes that caused those patterns, and (3) establish an archive of soil samples for use by future investigators. From 2007 to 2010, the U.S. Geological Survey (USGS) collected soil samples from 4857 sites throughout the conterminous United States as part of the NASGLP (Fig. 1A). The purpose of this paper is to use selected geochemical and mineralogical maps (areas outlined in Fig. 1B) to demonstrate broad-scale processes that control observed regional- and national-scale patterns of the distribution of elements and minerals in the different soil types of the conterminous United States.

2. Methods

All geochemical and mineralogical data for the conterminous United States were published by Smith et al. (2013b). This report (1) describes field sampling activities, sample preparation, and analytical methods, (2) gives details of the quality control protocols used to monitor the

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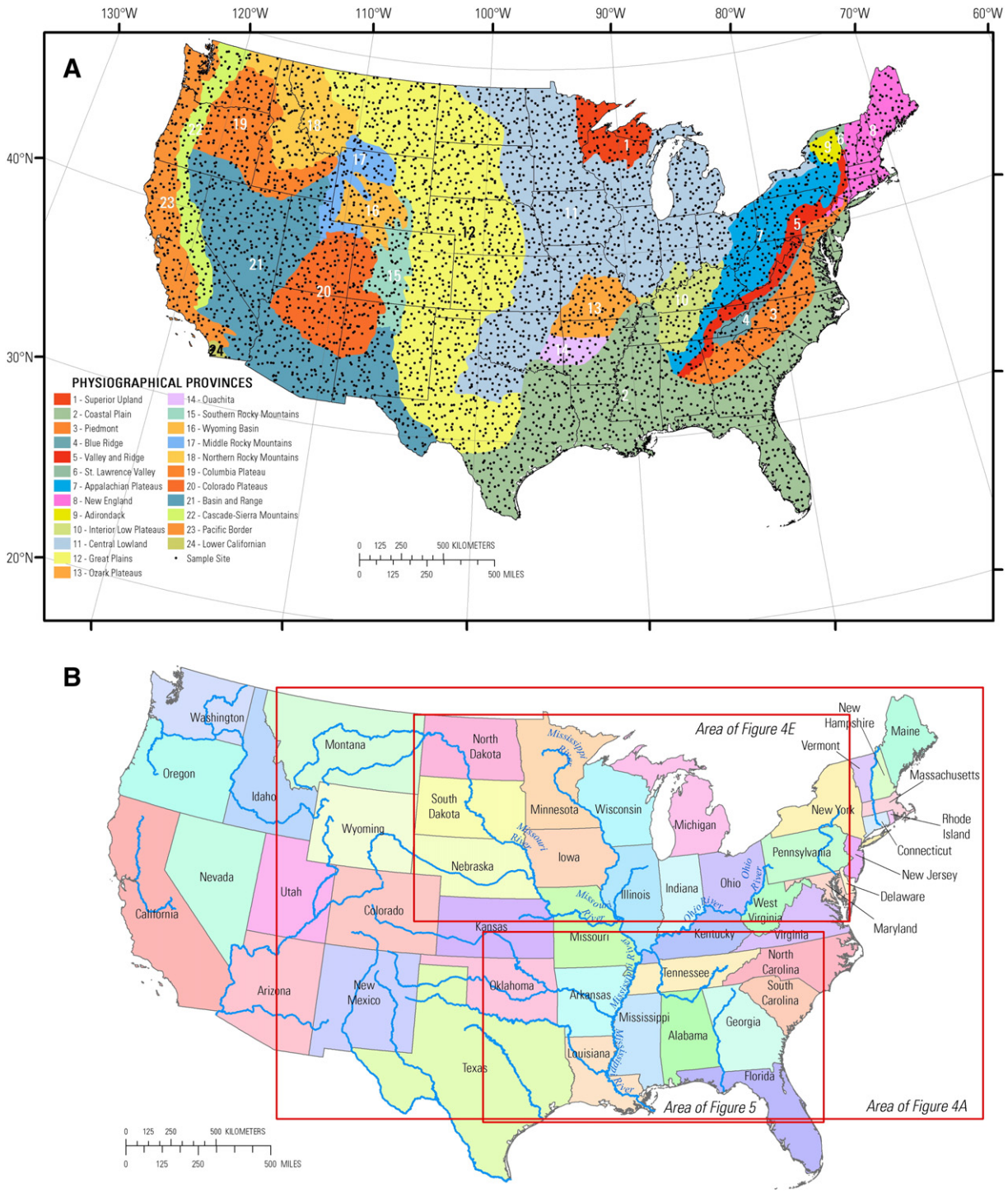

Fig. 1. (A) Distribution of soil sample sites (small black dots) displayed on a map of the physiographical provinces of the conterminous United States (Fenneman and Johnson, 1946). (B) Index map of the conterminous United States showing state names and major river systems (from www.nationalatlas.gov).

quality of chemical and mineralogical analyses generated over approximately six years, and (3) makes available the soil geochemical and mineralogical data. The report and analytical data are available for free download at http://pubs.usgs.gov/ds/801/. Interpolated maps showing the spatial distribution for each element and mineral and statistical summaries of all data are now available as a published report (Smith et al., 2014), and through an interactive web page http://mrdata.usgs.gov/soilgeochemistry/#/summary. Only a brief overview of sampling protocols and analytical methods provided in Smith et al. (2013b) are given below.

2.1. Soil sampling

Sampling for the national-scale soil geochemical and mineralogical survey of the conterminous United States began in 2007 and was finished in 2010. Chemical and mineralogical analyses of the samples were completed in May 2013. Sample sites were selected on the basis of a generalised random tessellation stratified design (Stevens and Olsen, 2003, 2004) at a density of approximately 1 site per 1600 km^2 (4857 sites for the conterminous United States) (Fig. 1B). This design produces a spatially balanced set of sampling points without adhering