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The regional geochemical baseline soil survey of southern New Zealand: Design and initial interpretation

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ABSTRACT

A multivariate geochemical baseline survey of soils from southern New Zealand has been completed. Soil samples were collected from 0 to 30 cm 'A-depth' and 50–70 cm 'B-depth' at 348 sites on an 8 km-spaced grid covering 40,000 km^2 of the Southland and southern Otago regions. The sub-180 μm fraction of all samples was analysed by inductively coupled plasma mass spectrometry following aqua regia (partial) digestion for 65 elements, and by Leco CS320 element analyser for total C and S. Sub-sets of the samples were analysed by XRF for 12 oxides/elements. Significant chemical variation in the soil samples can be linked to variations in source geology, soil type, climate and topography. Relatively high concentrations of certain elements (e.g. S, P, Pb, Hg, Cd), particularly in the A-depth, are attributed to anthropogenic sources such as fertilisers, paints, vehicle emissions or industrial emissions. Other elevated element concentrations, especially those in B-depth samples, are probably natural with high As, Bi, Sb and W reflecting proximity to Au mineralisation, Pt and Re near PGE mineralisation, and accumulation of heavy mineral-associated elements such as Cr in alluvium-derived soils related to the effects of both source material and hydraulic effects on flood plains. This study provides an important baseline that will benefit government, environmental, agricultural, forestry and mining sectors through improved regulatory guidelines and understanding of the regional geochemical landscape. This survey design, with minimal modification, is suitable for a national geochemical baseline survey for New Zealand.

1. Introduction

Geochemical datasets for soil and other surficial materials are an important component of environmental baseline studies. They can be used to assess the extent of anthropogenic activity superimposed upon natural influences (Plant et al., 2001). They are applicable to a wide variety of environmental and economic purposes such as the setting of environmental regulatory limits (Cohen et al., 2012; Darnley et al., 1995), soil fertility (Clare, 1981), forensic studies (Reimann and Caritat, 2012), public health (Plant et al., 2001), agriculture (Webber, 1981), forestry, water supply and irrigation (Purchase and Fergusson, 1986), waste disposal, mineral exploration and mining (Ward et al., 1977; Ward and Brooks, 1978), industrial pollution (Deely et al., 1992) and transport and urbanisation (Fergusson et al., 1980). A number of regional, national and continental-scale geochemical baseline soil surveys have been conducted in several parts of the world, including Europe (Cohen et al., 2011; Rawlins et al., 2012; Reimann et al., 2011a; Salminen et al., 2005), China (National Soil Survey Office, 1998), Australia (de Caritat and Cooper, 2011) and North America (Smith et al., 2013). There has been significant work in New Zealand to understand soil distribution, development and properties. For example, Landcare Research has synthesized soil surveys over most of New Zealand into a single data layer: the Fundamental Soils Layers, which shows important chemical attributes such as minimum pH and total Carbon (soils.landcareresearch.co.nz/contents/SoilData_FSL_Maps; accessed 14 April 2016). This is being replaced by S-map: the digital soil spatial information system for New Zealand (Lilburne et al., 2004). S-map online (smap.landcareresearch.co.nz; accessed 14 April 2016) currently shows soil type, drainage, depth and moisture content amongst other factors for some parts of New Zealand. Numerous soil chemical studies have been undertaken from selected sites in New Zealand for a variety of purposes (e.g. Childs et al., 1983; Kirkman et al., 1994), including the *500 soils project* which sampled across New Zealand (Sparling et al., 2004 and references there-in) with 511 sample sites (excluding Southland and Westland) and which focussed on soil quality measurements (such as total C and

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N) rather than contamination or chemical baseline aspects. Yet, despite a long history of soil-related research in New Zealand, there has not been a systematic, grid-based national or regional study of the chemical composition of New Zealand soils, until now.

New Zealand represents a unique setting with respect to determining the natural geochemical baseline of soils. Unlike many other regions, New Zealand is sparsely populated and has a relatively short history of human occupation and land-use disturbance. Furthermore, significant tracts of New Zealand are designated as National Park (10% by area), and have had very minor anthropogenic modification. About 20% of New Zealand is public conservation land, with varying but generally low levels of anthropogenic influence. The relatively pristine nature of around a third of New Zealand's territory means that the natural geochemical background of its soils can be established and compared to soils in other areas with similar geological conditions that have been affected by anthropogenic activities.

A regional, grid-based geochemical baseline soil survey has been completed in the southern part of New Zealand's South Island (Martin et al., 2015; Fig. 1). This paper presents the background, chemical results, methodology and quality assurance and quality control (QAQC) approach for the first New Zealand regional survey and presents highlights of the chemical data. These results have been examined for the adequacy of the survey design to show expected geochemical patterns, for example from underlying geology or anthropogenic input, and how the choices of survey design (such as sample spacing and analysis method) affected the chemical results. Finally, the suitability of the survey design for application to a national New Zealand survey will be assessed.

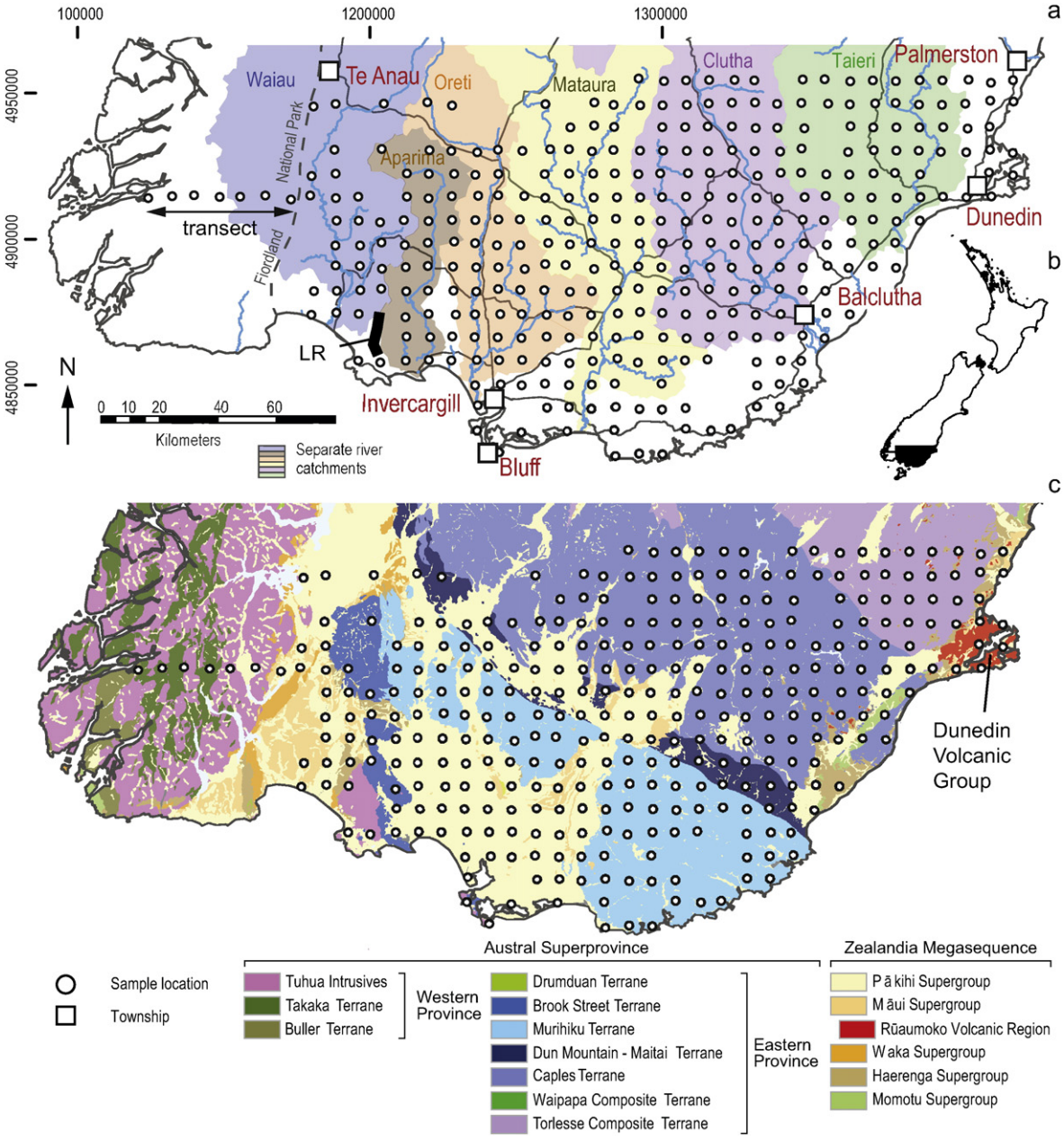

Fig. 1. Diagrams of soil sample locations in the southern South Island of New Zealand with river catchments and geology. a. Soil sample locations with major townships, roads, rivers and river catchments marked. Fiordland National Park is to the west of the dashed line and was sampled along one, west-east transect. LR = Longwood Range. b. Coastline of New Zealand showing the survey location. c. Soil sample locations with major lithostratigraphic units after Edbrooke et al. (2015) shown. The composition of each unit is summarised in Table 1.