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Application of environmental magnetism on crime detection in a highway traffic accident from Yangzhou to Guazhou, Jiangsu Province, China

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ABSTRACT

Both elemental composition analysis and mineral magnetic measurements were used to infer the source of the earth dumped on a highway in China, which resulted in human life loss and injury in 2002. The results indicate that the earth and the samples from the potential two sources are very similar in geochemical compositions. However, magnetic properties show stronger difference among the samples. A plot of magnetic susceptibility (χ) vs. Anhysteretic Remanent Magnetization (ARM) clearly show that the earth at the accident site (sample No. 1) is closely matched with one sample (No. 4) from the source site B. Such a difference in geochemical and magnetic signatures among the samples is ascribed to the nature of the earth, which is derived from the Xiashu Loess in southern China. Our results indicate that environmental magnetic method can help to crime investigation by aiding in the provenance tracing of soils/sediments evidences in a simple, economic and non-destructive way.

1. Introduction

Soil and sediment analysis has been widely used to make comparison between samples and provenance ascription in forensic enquiries [1]. With the development of geoscience, a number of analytical techniques have been applied to geoforensic investigations, including soil color [2,3], particle size composition [4–6], pollen [7], mineralogy [8] and geochemistry [9,10].

Soil or sediment analysis can be grouped into destructive and non-destructive methods. Sometimes there is very limited amount of the samples in geoforensic investigation. Apparently, non-destructive method is preferred as it may leave the sample for additional analyses. Since the 1970s, the development of environmental magnetism has provide a new approach characterizing the samples in terms of magnetic mineralogy and its concentration and grain size [11–14]. By virtue of magnetic measurement being rapid, simple, economic, sensitive and non-destructive, environmental magnetism has been widely employed in geoscience studies [15,16]. It has been successfully used in the source ascription in a number of environmental medias, such as aerosol, loess, and fluvial, lacustrine and marine sediments [17–19]. A forensic application of this method, however has rarely been reported [20–22], although it has been suggested as a geophysical technique in geoforensic survey.

In this paper, we demonstrate the usefulness of environmental magnetic method in geoforensic study through an example of sediment provenance ascription in a traffic accident happened in China.

2. Samples and methods

2.1. The traffic accident and sample collection

On 13th June 2002, a traffic accident took place at early morning on No. 243 highway (linking the city of Yangzhou and Zhenjiang city, both of which belong to Jiangsu Province, China) at 4.8 km away from Yangzhou city, Jiangsu Province (see Fig. 1). A small agricultural vehicle with three wheels was crashed by a truck (Jiefang or Dongfeng model, with cargo tonnage about 10 tons) with high speed. One of the two people in the small vehicle, the driver and his wife, was dead and the other was injured seriously in the accident. The truck was damaged heavily, but no people were injured. The investigation revealed that the cause of the traffic accident was due to a heap of earth (about 10 tons) on one side of the highway. The earth was unloaded illegally by one of the lorries transporting loess sediment from the Sugang Hill (Fig. 1) to construct the Runyang Bridge across the Yangtze River (Changjiang). A lorry was broken and the earth to be transported by the lorry was therefore unloaded on the highway in the afternoon or at night probably. The right side of the way to Guazhou direction was occupied by the heap of earth. The small vehicle first bumped on the heap at about 2:00–5:00 in the early morning, turned over on the

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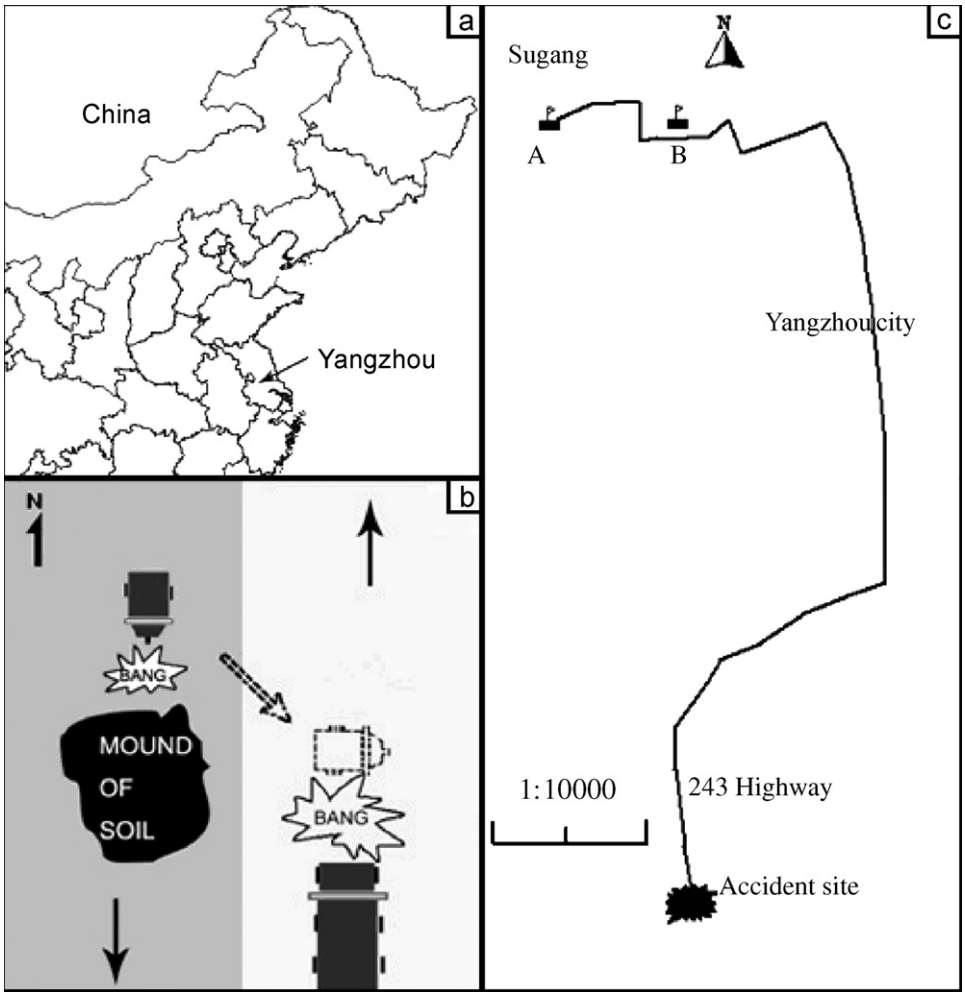

Fig. 1. Map showing the traffic accident on the Yangzhou–Guazhou Highway, China. (a) Location of Yangzhou city in China. (b) Sketch map of the accident site. (c) The position of the accident site related to the earth source sites A and B of the Sugang Hill.

left side of highway to Guazhou direction, when the truck crashed the small vehicle. On those days, there were only 4 motorcades and about 130 trucks were transporting earth for the construction of the Runyang Bridge. Since there was no eyewitness in the dark early morning or evening and no driver acknowledged the dumping of earth on the highway, identification of the source of the earth unloaded on highway is crucial to the determination of the motorcade and the responsible lorry. Because all the earth to be used for bridge construction came from two small mounds within a distance of 3 km on the Sugang Hill, the earth unloaded on highway must be from one of the two small mounds. It was found difficult to distinguish the earth from the two mounds in field observation, as they all composed of loess deposition of Pleistocene age.

Nine samples were collected from three locations, i.e. No. 1 sample at the accident site, and No. 2–3 samples from site A and No. 4–9 samples from site B of the Sugang Hill (Fig. 1).

2.2. Conventional soil analysis method

All the samples were analyzed with routine methodology of soil science, e.g., soil color, particle size, pH and element composition [23].

Soil color was directly observed on air-dried samples using Munsell soil color chart. For particle size analysis, the samples were treated with hydrochloric acid and hydrogen peroxide to remove carbonates and organic matter, respectively and then dispersed with hexametaphosphate. The sand fraction (>63 μm) was separated by passing the samples through a sieve with 63 μm mesh size and weighed. The clay (<0.005 mm) and silt (0.05–0.005 mm) fractions were determined by the principle of Stocks law with a Bouyoucos hydrometer. Soil pH was measured with a water to soil ratio of 5 using an IQ 150 pH Meter (Spectrum Technologies company, U.S.A.).

All air-dried samples (except sample No. 9 due to not enough quantity) were ground into powders and analyzed for Al, Ca, Fe, K, Mg, Mn, Na, Si and Ti by X-ray fluorescence spectrometer (XRF-1800). China Sediment Reference Material (GSD9) was analyzed along with the samples for quality assurance purposes. The metal analytical concentrations for GSD9 were within ±10% of the range of the certified value.

2.3. Environmental magnetic measurement

All samples were oven-dried at ≤45 °C temperature, then gently disaggregated, weighted and packed into the 10 ml plastic sample vials. The sequence of magnetic measurement was as follows [24,25]: (1) low frequency (470 Hz) and high frequency (4700 Hz) magnetic susceptibility (χ_{LF}, χ_{HF}); (2) Anhysteretic Remanent Magnetization (ARM) (alternating magnetic field peak value 100 mT, with biasing direct current field 0.04 mT); (3) Saturation Isothermal Remanent Magnetization (SIRM) (magnetic field 1 T). The instruments include Bartington MS2 magnetic susceptibility meter, Molspin demagnetiser, pulse magnetiser and Minispin magnetometer. According to the measurement, mass-specific parameters χ, SIRM and ARM, and ratios $\chi_{fd}\%((\chi_{LF} - \chi_{HF})/\chi_{LF} \times 100)$, SIRM/$\chi$ and ARM/χ were calculated. Magnetization vs. temperature curves were obtained with the MMVFTB (Variable Field Translational Balance) in air using a field of 42 mT. The unit and a brief interpretation of the magnetic parameters were listed in Table 1.

3. Results

3.1. Sample characterization by conventional soil analysis

The physical characteristics of the samples are given in Table 2. According to the Munsell soil color chart, the difference of color among the samples is not significant (Table 2), with red and yellow being the dominant color. Samples No. 4, No. 5, No. 8 and No. 9 are yellow and umber color, and sample No. 3 and No. 7 are red and