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DETECTION OF LANDFILL´S LEAKAGES USING AIRBORNE GEOPHYSICS

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Abstract. Since 1972 the Geological Survey of Finland (GTK) has carried out low altitude geophysical surveys and today systematic survey data cover the majority of Finland. The survey was conducted using geophysically instrumented aircraft with GTK's Three-In-One airborne system (i.e. simultaneous measurements of the earth´s magnetic field, radioactivity and electrical conductivity). The survey started as a geological mapping for mineral exploration, but in recent years airborne data have been used successfully especially in environmental applications related to landfill, groundwater and soil contamination. The paper presents two studies where GTK´s airborne data have been successfully applied for environmental purposes. The first example is from Ämmässuo, south Finland, where GTK has carried out landfill monitoring using airborne geophysics. The airborne measurements conducted four times over the Ämmässuo municipal landfill. The second example is from Mäntyvaara landfill, north Finland. An increased electrical conductivity outside the landfill was discovered during routine mapping flights.
GTK's three-in-one airborne system is efficient and fast method to locate possibly leakages at landfills. It helps to focus the more detailed investigations (i.e. ground geophysics, sampling and chemical analyses) to the most suitable locations. Interpretation of bedrock linear features using airborne total magnetic field maps is useful tool for detecting possible path of leakages. The electromagnetic out-of-phase component is the most sensitive parameter to observe slight changes in conductivity, but also other measured parameters can utilized.

Key words: airborne, geophysics, electromagnetic, environment, landfill, leakage.

Abstrakt. Od 1972 roku Służba Geologiczna Finlandii podejmuje badania geofizyczne na niskich wysokościach i obecnie systematyczne dane obejmują większość obszaru Finlandii. Prace badawcze prowadzone były z użyciem samolotu wyposażonego w instrumenty geofizyczne z systemem GTK Trzy-w-jednym (tzn. jednoczesne pomiary pola magnetycznego Ziemi, radioaktywności i przewodności elektrycznej). Badania rozpoczęte zostały jako kartowanie geologiczne w celu poszukiwania złóż, przy czym obecnie dane lotnicze używane są z powodzeniem w zastosowaniach środowiskowych w odniesieniu do składowisk, wód podziemnych i kontaminacji gleb.
Praca prezentuje dwa przykłady pozytywnego zastosowania danych lotniczych GTK do celów środowiskowych. Pierwszy przykład pochodzi z Ämmässuo, na południu Finlandii, gdzie GTK przeprowadzało monitoring składowiska przy użyciu powietrznej geofizyki. Pomiary przeprowadzano czterokrotnie nad miejskim składowiskiem Ämmässuo. Drugi przyklad pochodzi ze składowiska Mäntyvaara, na północy Finlandii.W trakcie rutynowych lotów kartograficznych wykryto podwyższoną przewodność elektryczną na zewnątrz składowiska.
System GTK jest wydajną i szybką metodą lokalizowania możliwych przecieków na składowiskach. Pozwala ukierunkować szczegółowe badania w najbardziej istotnych miejscach (tzn. geofizyka gruntu, opróbowanie i analizy chemiczne). Interpretacja struktur liniowych podłoża przy użyciu powietrznych map całkowitego pola magnetycznego jest użytecznym narzędziem śledzenia potencjalnych ścieżek wycieków. Elektromagnetyczna składowa pozafazowa jest najczulszym parametrem obserwacji niewielkich zmian przewodności, ale mogą być użyte również i inne parametry.

S[3]owa kluczowe: powietrzny, geofizyka, elektromagnetyczny, środowisko, składowisko, wyciek.

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INTRODUCTION

Finland is one of few countries in the world to have undertaken a modern nation-wide airborne geophysical survey of its territory. Since 1972 the Geological Survey of Finland (GTK) has carried out low altitude geophysical surveys. Today systematic survey data cover the majority of Finland and the project will be finished in 2008. The survey started as the geological mapping for mineral exploration, but recent years the airborne systems has been used more for environmental applications.

GTK has conducted many aerogeophysical studies of landfill areas in Finland. The Three-In-One airborne system (i.e. simultaneous measurements of earth´s magnetic field, radioactivity and electrical conductivity) gives a detailed information of large areas. The unit cost are low and it helps to focus more detailed investigations (ground geophysics, sampling and chemical analyses) to the most suitable locations.

In the present paper two examples are presented. The first example is Ämmässuo, a large modern municipal landfill of Helsinki region, where the arrangements are up to date. The second example is Mäntyvaara landfill in Rovaniemi, north Finland. It is an example of the old hazardous landfill.

MEASUREMENTS

GTK has been operated with two aircrafts, Twin Otter and Cessna Caravan. The airborne geophysics survey with fixed wing aircraft Twin Otter are jointly carried out by GTK and the British Geological Survey (BGS). This Joint Airborne-geoscience Capability (JAC) provides data for national strategic science programmes and surveys for third parties. The present geophysical equipment installation consists of four frequency electromagnetics, magnetic gradiometer and 256 channel radiometrics (Fig. 1) The fixed wing survey aircraft Cessna caravan has been used in the Finnish national mapping program and for numerous surveys for clients in Finland and abroad. The standard assembly is dual frequency electromagnetics, magnetometer on tail stinger and 256 channel radiometrics. In systematic nation-wide airborne surveys the flight altitude is usually 30-40 metres and the line spacing is 200 metres, but in specific measurements even spacing of 50 metres can be used. More about GTK´s three-in-one system is in presented by Airo (2005).

Using the three-in-one airborne system to locate possible leakages from landfills can be seen in different aspects from all three components. The electromagnetics indicates an increased electrical conductivity. The electromagnetic measurements using multi frequencies are most suitable for a classification of environmental effects. The electromagnetic out-of-phase component is particularly sensitive to detect small changes in conductivity (Lohva *et al*., 1999). Magnetic data indicate metallic waste and constructions. Using radiometric data, the changes in moisture and the soil thicknesses can estimated.

Fig. 1. Twin Otter aircraft with three-in-one aerogeophysical system

THE ÄMMÄSSUO LANDFILL

Ämmässuo is a large municipal solid waste landfill of the Helsinki region in southern Finland. An operation of the landfill began in 1987. The landfill is built on the bedrock comprising a highly resistive Fenno-Scandinavian granitic shield. The bedrock has been isolated by plastic covers. Ground and surface waters are monitored regularly. An aerial view of the Ämmässuo landfill is shown in Figure 2.

The Ämmässuo region has been mapped four times by GTK. The first airborne survey in the Ämmässuo area was conducted as a part of the systematic mapping program in 1984,

Fig. 2. Aerial view of the Ämmässuo municipal solid waste landfill

before the beginning of the landfill operation. Then the flights were repeated in 1993, 1997 and 2003. The 1984 measurements were made using 200 m line spacing, while later flights were carried out in 100 m line spacing.

Regional airborne total magnetic field maps have been used to interpret linear features of the bedrock. The lineaments support a detection of possible path of leakages. The airborne total field magnetic maps (Fig. 3) from the Ämmässuo area cover the history of the landfill activity. In 1984 this area was in a natural condition. The measurements conducted in the period from 1993 to 2003, i.e. after the operation began, show how the magnetic data indicate an amount of metallic wastes as well as human constructions.

The airborne electromagnetic out-of-phase component is the most sensitive parameter to observe slight changes in conductivity. The airborne electromagnetic out-of-phase component maps from the Ämmässuo landfill are shown in Figure 4.The 1984 results illustrate the natural state of the site before the landfill was established. It outlines the wet marshlands from generally resistive environment. Roads and a border of the landfill are marked to the map as they are nowadays. The 1993 airborne data have been used for selecting locations for further ground surveys and monitoring wells. The ground geophysical measurements have been carried out to verify the airborne anomalies, as well as to study the accuracy of the geophysical methods detecting landfill contamination (Lohva *et al*., 2001; Vanhala *et al*., 2000). In all three airborne measurements, after the landfill's operation began, the heap of the domestic waste appears as a high conductive anomaly. The landfill anomaly follows quite precisely the boundaries of the filling area. The airborne electromagnetic anomalies outside the landfill illustrate the wet marshlands and relatively small clay deposits. The conductivity anomaly north of the landfill is a separate soil dump site of the city of Espoo. The conductivity changes that might reflect the landfill impacts located southwest of the landfill. The groundwater is monitored by sampling and laboratory analysis and so far there is no indication of a groundwater contamination.

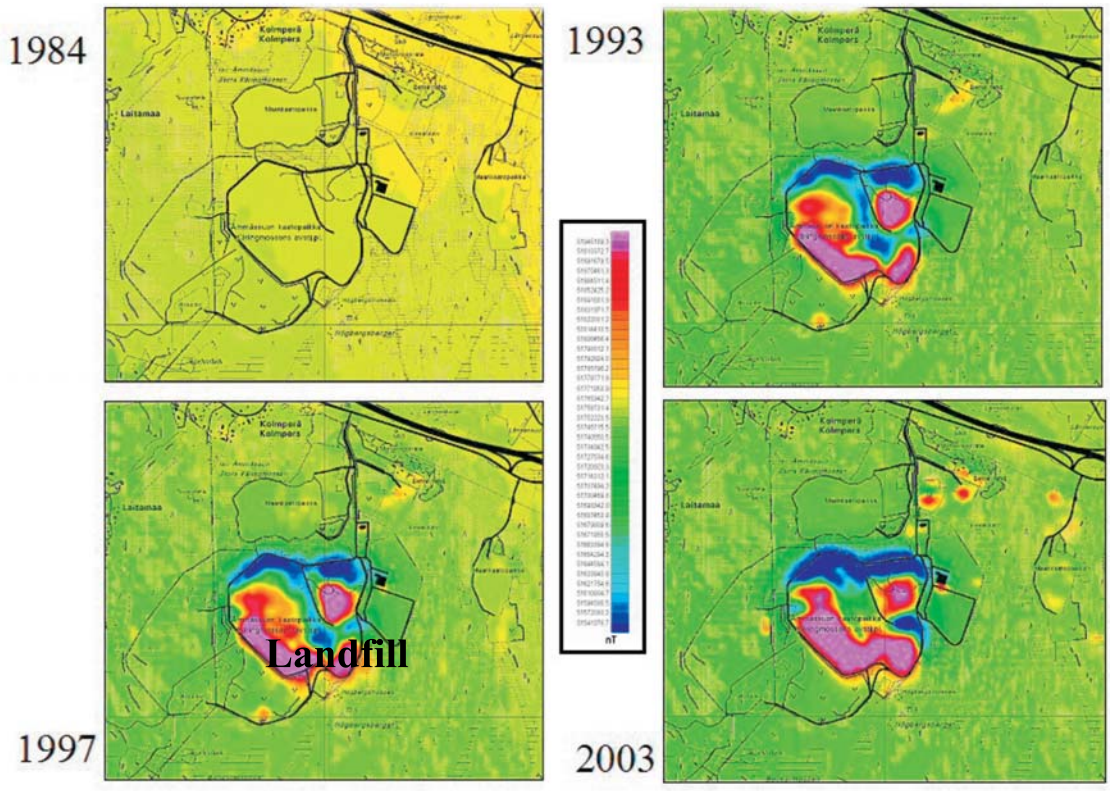

Fig. 3. The airborne total magnetic field maps from the Ämmässuo landfill

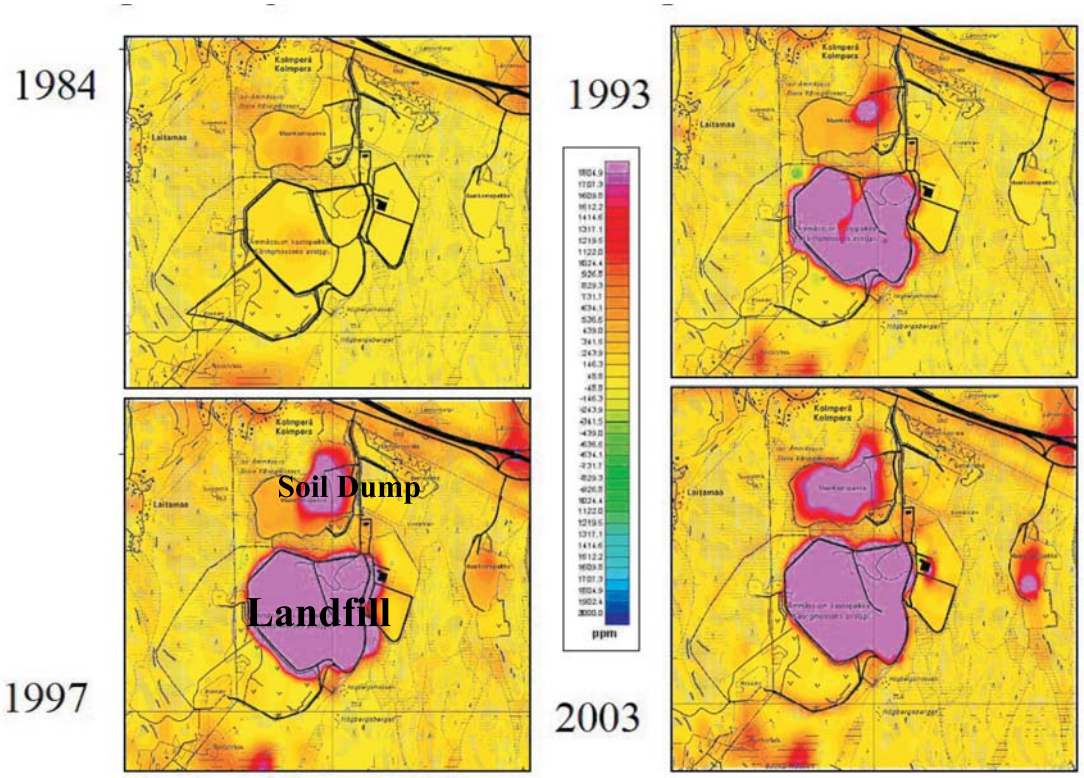

Fig. 4. The airborne electromagnetic out-of-phase component maps from the Ämmässuo landfill

Purple colour indicates a strong electrical conductivity

THE MÄNTYVAARA LANDFILL

The Mäntyvaara landfill (the city of Rovaniemi, in northern Finland) was established in 1965 for municipal wastes, but hazardous wastes were dumped there without control until 1984, when the landfill was closed (Hannula, Lanne, 1995). The landfill was established on a bog. The study over the Mäntyvaara municipal landfill was the first case in Finland, where the airborne electromagnetic data were used for mapping of contaminated areas (Sutinen *et al*., 1994). An increased electrical conductivity south-east of the landfill was discovered during routine mapping flights in 1992 (Fig. 5). The salts,

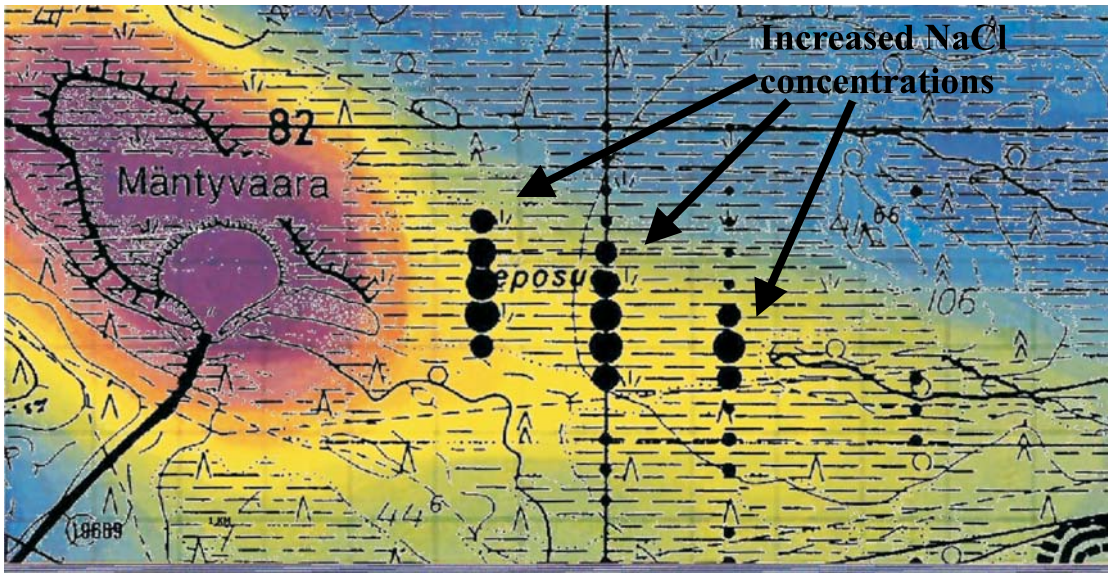

Fig. 5. The airborne electromagnetic out-of-phase component map from the Mäntyvaara landfill

which were dissolved from the waste, are the reason for electrical anomaly (Jokinen and Lanne, 1996). Geophysical and geochemical ground measurements were carried out confirming the airborne anomaly and showed the increased conductivity and concentrations of inorganic and organic contaminants.

CONCLUSIONS

The GTK's three-in-one airborne system is an efficient and fast method to locate possible leakages at landfills. It helps to focus more detailed investigations (i.e. ground geophysics, sampling and chemical analyses) to the most suitable locations.

An interpretation of bedrock linear features using airborne total magnetic field maps is a useful tool for detecting possible paths of leakages. The electromagnetic out-of-phase component is the most sensitive parameter to observe slight changes in conductivity, but also other measured parameters can utilized. The environmental impacts can be studied more accurately if repeated measurements are carried out. Then the changes in the environment can be distinguished more reliably from the natural conditions.

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