# Abstracts of other papers/posters presented at the Annual Conference, January 2002


## Palynology of the Late Triassic and earliest Jurassic succession (Mercia Mudstone and Penarth groups, and the basal Lias): south-east Devon and south-west Dorset

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Results of palynological studies of outcrop sections of the upper Mercia Mudstone Group east of Seaton, and of the Penarth Group and basal Lias Group in a borehole at Charmouth, supplement those previously available from outcrops between Sidmouth and Branscombe and from the Lyme Regis and other boreholes. Palynomorphs have not been recovered from the lower c.155 m of the Mercia Mudstone Group but miospores of Carnian age occur in the succeeding c.75 m of that group. No significant assemblages are known from the succeeding c.130 m of the Mercia Mudstone Group. Miospores of Norian(?) age are recorded from c.37 m and c.25 m below the Blue Anchor Formation. Marine palynomorphs (acritarchs) and remains of foraminifera appear in the Blue Anchor Formation, c.27 m below its top, and miospores from the upper c.17 m of that formation are indicative of a Rhaetian age. The miospore assemblages diversify upwards through the upper part of the Blue Anchor Formation and the succeeding Penarth Group. Marine dinoflagellate cysts of the Rr and Dp biozones appear, respectively, at the base of the Penarth Group and near its top, in the upper part of the Lilstock Formation. Miospore associations of limited diversity, and acritarch-dominated marine microplankton associations, occur in the Lias Group.

## A petrographic study of some septarian concretions from the Stewartby Member (Lower Jurassic, Oxford Clay) of Dorset

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Two concretions collected from Chickerel Brick Pit, west of Weymouth, Dorset in the Athleta biozone of the Stewartby Member of the Oxford Clay Formation have been studied. The concretions posses a crude zonation with the body of the concretion being composed of non-ferroan calcite microspar with minor pyrite and quartz with an infrequent outer zone of equal non-ferroan microspar and non-carbonate minerals (clays, quartz and pyrite). Framboidal and crystalline pyrite concentrations are highly variable. The concretions are moderately bioturbated with *Chondrites* dominating. The lack of compaction-related features, with for example, the retention of burrow morphology indicates a pre-compaction relative age for these concretions.

These concretions have undergone burial and have developed extensive septarian fracturing which has brecciated the rock mass. Fractures penetrate to the rim, and there is evidence of internal collapse forming "doughnut-ring" morphologies. The fracturing of the cemented sediment occurred in three main phases, each of which cross-cuts the previous. The first fractures generated are simple sigmoidal fractures filled with brown non-ferroan non-luminescent calcite. The subsequent phase is less apparent but is composed of brown non-ferroan bright orange luminescent calcite. These earlier brown calcites show undulose extinction and have scalloped margins. Postdating these cements are initially a sequence of clear dull orange inclusion-rich ferroan calcite followed by internally cathodoluminescence zoned bright and dull orange clear ferroan calcite.

The nucleation point of the concretions is unknown, however, the precipitation of the body occurred rapidly and reached full size very early, most likely within the sulphate reduction zone. The multiple phases of fracturing and septarian calcite infill occurred over an unknown time span in which repeated stress build up and release occurred. The mechanism is not certain but is thought to be related to over pressuring within the clay host rocks at shallow depths (<1 km) with fracturing aided by pore fluid interaction. The evolving septarian fill proves that with time the concretions were progressively buried as the pore water source from which the calcite precipitated changed from marine influenced to burial (and/or meteoric) influenced.

## A comparison of the North Atlantic cycle of the United Kingdom with the Greenhorn cycle of the United States: evidence from south-west England

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In the recently published Mesozoic and Cenozoic sequence stratigraphy of European basins Thierry Jacquin and Pierre-Charles de Graciansky (1998) describe the "North Atlantic Cycle" as one of the four major transgressive/regressive cycles seen in European sedimentary basins. This cycle occupies the interval of time between the late Cimmerian unconformity and the Laramide unconformity. Within this the authors recognise six 2nd order cycles while other authors, working on 3rd order cycles, have identified a considerable number of quite widespread sequence boundaries and flooding events. Many of these can be

readily identified in the marginal mid-Cretaceous succession of south-west England. In the United States of America the Cretaceous Western Interior Seaway records a very similar sedimentary record and this "Greenhorn Cycle" contains many of the events (and microfaunas) that we see in the United Kingdom, and south-west England in particular.

## A new, linked tectonic model of Variscan structure in the Bristol Channel area: the Cannington, 'Exmoor', Bristol Channel and Watchet – Cothelstone structures resolved

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The marine waters, Quaternary sediments and Mesozoic succession of the Bristol Channel conceal major Variscan structures separating the two distinct Palaeozoic terranes of southwest England. Mapping of seismic reflectors from the Bristol Channel reveals at least two ESE-WNW striking thrusts within the Palaeozoic sequence. The more southerly, with a moderate SSW dip, has previously been identified as the Bristol Channel Thrust. In the west of the inner Bristol Channel, it separates a southerly sub-Mesozoic sequence containing a prominent reflector from a strongly reflective northern sequence. The Bristol Channel Thrust is interpreted as the main Variscan structure separating the onshore Palaeozoic terranes. Another thrust, the previously undescribed Gravel Margin Thrust, occurs only in the eastern part of the inner Bristol Channel and lies in the footwall of the British Channel Thrust. It has a similar strike but steeper SSW dip. The Gravel Margin Thrust and the British Channel Thrust together juxtaposed the contrasting (South Wales and Devon/Cornwall) Palaeozoic rocks prior to Mesozoic reactivation. Onshore geological mapping along the North Devon coast shows that the Bristol Channel thrust and Gravel Margin Thrust have orientations and geometries typical of many thrusts observed and measured at Foreland Point (North Devon). In particular, the Lynton Fault is used here as an analogue for the early history of the Gravel Margin Thrust. In addition, an antiform at Foreland Point, displaying the geometry of a hangingwall anticline, strongly suggests the presence of at least one further thrust immediately offshore (the North Devon Coastal Thrust). Along-strike structural changes beneath the inner Bristol Channel (as indicated on the seismic reflection sections) provide evidence, in addition to earlier refraction and structural studies, for the offshore continuation of the NW-SE trending Watchet-Cothelstone-Hatch Fault and its linkage with the Central Bristol Channel Fault Zone. The long-debated origins of the Bristol Channel and Gravel Margin thrusts and the Cannington Park Thrust are now resolved by the 14-16 km strike slip offset of the Watchet-Cothelstone-Hatch Fault displacing these structures. A corollary is the correlation of the Gravel Margin Thrust and Cannington Park Thrust as syngenetic structures linked by their lateral ramp, the Watchet-Cothelstone-Hatch Fault. With these problems resolved, the structure of the partially-obscured Variscides of the inner Bristol Channel can now be re-evaluated and a new model introduced.

## The geochemistry of the late-Carboniferous, early-Permian minettes of South Devon

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Mid-Devonian to Upper Carboniferous slates, limestones and grits are intruded by one or possibly two minette dykes south of Dartmoor in the vicinities of Buckfastleigh and South Knighton, near Newton Abbot. The two dykes can be traced for approximately 11 km from the University of Plymouth (Seale Hayne Agricultural College) to Buckfastleigh, trending ENE-WSW. The rocks have moderate to high concentrations of Ni and Cr, which suggest that both have to some extent been fractionated. The minettes are strongly enriched in LREE and LILE elements, with notable depletions in Nb and Ti relative to LEE. These features support the view that the minettes are subduction related. The minettes are possibly derived from an ultimate source in lithosphere subducted or down thrust during the Varsican orogeny. The minette dykes are chemically similar to the potassic lavas of the Exeter Volcanic rocks, suggesting that they are genetically related.

## Acid rock drainage at Venn Quarry, near Barnstaple, North Devon

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Venn Quarry produces high polished stone value (PSV) aggregates, used for skid-resistant road surfacing, from interbedded marine sandstones and shales of the Upper Carboniferous Crackington Formation. Minor proportions of organic, sulphide-rich black shales are the primary cause of the acid rock drainage generation at the quarry. Mineralisation is finely disseminated, largely comprising of sphalerite, galena, chalcopyrite along with a high proportion of framboidal and cubic pyrite.

The mineralisation originated under anoxic marine conditions and the sulphides therefore alter readily on exposure to oxidising conditions. Oxygenated groundwater seeping through fault-zones lined with black shale are the primary zones of acid rock drainage generation. The waste tips containing shale waste from quarrying are also generating acid rock drainage.

The acid rock drainage is high in Zn and Al, and occasionally Cd. Discharge from the quarry to the river is being managed and treated to Environment Agency standards. Higher proportions of black shale occur in the lowest strata exposed along the northern edge of the quarry, evidently the Ashton Shale Member which occurs throughout the Culm Basin as a sulphide-rich unit at the base of the Crackington Formation. The acid rock drainage generation within the quarry is extremely rapid and is likely to involve the catalytic action of bacteria, particularly *Thiobacilus ferrooxidans*.

## Sampling of particulate materials – what you didn't know

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Sampling is an expensive, time-consuming, sometimes unavoidable activity which may give you the wrong result! So why bother? Fortunately the value of sampling can be preserved given proper understanding of the basics. Do not consider sampling as a process where every element will be given an equal opportunity to be sampled, don't base your conclusion on raw sample analyses, don't sample more than necessary. In order to put these don'ts into practice, a framework is presented for analysing the mechanics of sampling and making inferences in a cost-effective manner. As a practical application, sampling of a contaminated site is discussed.

## Handling geological uncertainty - risking petroleum systems

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A petroleum system comprises all hydrocarbon derived from a single volume of mature source rock (Magoon and Dow, 1994) and can be described in terms of quantity, composition and efficiencies. A feature of a petroleum system is the ability to quantify petroleum accumulation in terms of generated, migrated and entrapped masses or volumes. The petroleum system-efficiency is defined in terms of the discovered 'in-place' volumes as a fraction of the total petroleum volumes generated from the specified contributing source rock.

With a simple algebraic approach, the efficiency of a petroleum system can be calculated from source rock properties, maturity-related rock volumes and efficiencies of expulsion, migration and entrapment. Using Monte Carlo or Latin Hypercube sampling of these input distributions, the calculation can be risked to give a probabilistic estimate of the efficiencies of the individual processes and of the petroleum system as a whole. Large data sets from a number of basins are examined to investigate the form of appropriate distributions of input variables for such calculations. The large data sets required to capture the natural variability of the inputs commonly comprise between 500 and 15,000 samples. The measured distributions are characterised by arithmetic mean, standard deviation and skewedness, with normal, logarithmic, Erlang and Rayleigh curves best fitting natural data.

The hydrocarbon yield (kg oil/tonne rock) is a function of TOC and kerogen type. While large TOC data sets produce strongly log-normal distributions, it is the high-value tail that contains the oil and gas source rocks. If only source rocks are considered the skewedness is strongly reduced. The Hydrogen Index of immature source rocks represent kerogen type and are normally distributed, though if non-source rocks are included a negative skewedness is introduced.

Uncertainty in mature rock volumes comprises errors in source rock kitchen area and thickness, both of which rely on seismic mapping. Given a seismic-derived map, maturity defines the kitchen area, but the steepness of the flank or faulted basin margin controls its distribution. Uncertainty in source rock thickness is controlled by the sedimentation regime for the interval, and may be positively or negatively skewed. Expulsion efficiency is quantified from pyrolysis data in the range of zero to 0.85, and the variability is shown to be positively skewed at low maturity and negatively skewed at high maturity. Standard deviations of ±0.1 to ±0.2 are observed. Migration, entrapment and survival of the accumulation to the present day, are shown, by elimination, to be skewed, as are overall petroleum system efficiencies taken from the literature.

## Petro-structural study of the Carnmenellis Granite pluton: emplacement mode and role of tourmaline in magnetic fabrics

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In order to gain information about the possible emplacement mode of the Carnmenellis Granite (Cornwall), a detailed petro-structural and magnetic fabric study was performed from 48 stations as regularly spaced as possible over the pluton. With the exception of a few stations located along the western border of the pluton, all the microstructures are "magmatic" suggesting that the the granite fabric was derived from the emplacement stage when the granite was not completely solid. A preliminary foliation and lineation map could be drawn from the anisotropy of magnetic susceptibility (AMS) measurements. However, despite the paramagnetic behaviour of the granite (no magnetite present), tourmaline is ubiquitous in addition to biotite and iron-bearing muscovite.

Since tourmaline has an "inverse" magneto-crystalline intrinsic anisotropy, its magnetic signal perturbates the normal signal due to the phyllosilicates. In order to overcome the magnetic signal of tourmaline, the specimens were heated in-air at 650°C over 2 hours. This helped the growth of magnetite grains out of biotite. These new magnetites were demonstrated to be magnetically mimetic with respect to biotite and re-inforce dramatically the magnetic signal of the phyllosilicates. The new structural map of the Carnmenellis Granite, obtained after new AMS measurements, is compared with the original one. A dominant NW-SE trend of shallowly plunging lineations still persists and is attributed to magma stretch along this direction during pluton emplacement within its overlying country rocks. This agrees with some of Ghosh's field measurements (1934), and with already existing regional reconstructions. In addition, a conspicuous NE-SW lineation trend is revealed, in places where the tourmaline content is possibly the highest, particularly along a NE-SW trending corridor crossing through the pluton at its centre. These NE-SW trending domains and lineations are ascribed to late-magmatic tension-gashes along which the magma was flowing and the late, boron-enriched, fluids were collected. The challenge is now to verify whether this local peculiarity persists regionally by examining the behaviour of other Cornish plutons such as the Bodmin Moor Granite.

## Arsenic in SW England: a geological perspective and current BGS studies related to mining

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Whilst issues related to arsenic in South West England have been the subject of continued research over the years the forthcoming adoption of risk assessment methodologies by regulatory agencies, an increasing interest in human health

related issues and the requirements of PtIIA of the Environment Act 1990 is resulting in a renewed interest in this area. This series of presentations highlight work being undertaken by staff of the British Geological Survey, the Environment Agency and others in the South West which are of direct relevance to the issue of development in areas subject to elevated levels of naturally occurring and man-made sources of arsenic.

## Measurement of the bioaccessibility of arsenic in Devon soils

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Until recently, assessing possible risk to human health from arsenic in soils was based on the Interdepartmental Committee on the Redevelopment of Contaminated land (ICRCL) trigger levels for total soil arsenic concentration. These are 10 mg/kg for gardens and allotments and 40 mg/kg for parks, playing fields and open space. These values indicate a threshold above which further investigation is required. For areas such as the south-west of England, where there are naturally high concentrations of arsenic in soils, these trigger values are regularly exceeded. Whether these soils pose a human health risk depends on the potential of the arsenic to leave the soil and enter the bloodstream. In this study, an in-vitro physiologically based extraction test, which mimics the conditions inside the human stomach, has been used to measure the bioaccessibility of arsenic on natural and mine-waste contaminated soils from the area around Gunnsilake in Devon. These results, in combination with tests identifying the chemical form of arsenic in the soil, are reported and their significance in estimating human health risks from arsenic in soils in the southwest of England is discussed.

## MINEO: Mapping mine waste in Cornwall using advanced Earth observation tools

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Cornwall, in common with many other regions of Europe, has a legacy of contaminated land following a long history of mining. As new industries replace this activity in the region's economy, there is a need to map contamination as a first step in cleaning up sites. The MINEO project is developing novel airborne and satellite techniques to speed up this process at six sites across Europe, including the Camborne-Redruth area. This talk described the project and presented the first results, before considering future extension of the airborne techniques used so far to satellite sensors.

## The environmental impact of historical mining on the Hayle Estuary, Cornwall

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The environmental impact of historical mining on the south-west Hayle Estuary, Cornwall, was investigated by collecting six cores from the estuary and examining the sediment geochemistry and mineralogy. The sediment geochemistry of all the cores shows very elevated levels of tin and copper (maximum Sn value of 7,041 ppm and Cu 10,409 ppm). Petrographic studies show a mineral assemblage dominated by cassiterite, pyrite and chalcopyrite with minor galena, sphalerite and arsenopyrite along with smelt products. The sediment geochemistry and mineralogy are interpreted to represent the input of mine waste tailings and smelt waste into the estuary. The catchment hydrology of the estuary was combined with historic mine records to assess the source and relative date of the contaminated sediments, revealing potentially 200 years of contamination during the mining period 1700-1900 from the six catchments that feed the estuary. The environmental impact of historic mine waste is significant, placing the Hayle Estuary second to the Fal Estuary as the most contaminated estuary in Cornwall. This contamination, however, will probably remain locked in the sediments and biologically unavailable, as long as the sediments are not disturbed.

## Rehabilitation of South Wheal Francis, an asbestos-contaminated mine site in Cornwall

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South Wheal Francis is an abandoned copper-tin mine situated approximately 3 km south east of Camborne, Cornwall. The site is of considerable archaeological interest in retaining many of the original mine structures and buildings, and has been developed as an industrial heritage site. Like other copper mines in the area, the site was found to be heavily contaminated with a range of heavy metals (Cu, As, Pb, Ni, Zn) and suffered the additional hazards associated with shafts, stopes and other voids; the buildings also required consolidation to make them safe for public access.

An unexpected contaminant discovered at the site was blue asbestos (the mineral crocidolite, a variety of the alkali amphibole riebeckite). The mine, which operated during the late 19th and early 20th centuries, was powered by steam produced by a bank of six Lancashire boilers. Blue asbestos was used for thermal insulation of the boilers and, when the mine closed in 1918 and the boilers were removed, the asbestos was simply discarded. During rehabilitation works in the area to make the site safe for public access, considerable quantities of blue asbestos were identified at or near the surface in and around the boiler house.

This paper describes the site investigation, the work undertaken to remove the asbestos, and the final rehabilitation of the site. Special problems relating to the distribution of asbestos (as discrete asbestos objects rather than as a dispersed contamination), the need to protect the archaeological features of the site, the disposal of material contaminated with both heavy metals and asbestos, the health and safety aspects of the site remediation, and long-term monitoring are also discussed.

## MAGNETIC FABRICS AND FOLD DEVELOPMENT AT LOW METAMORPHIC GRADES – AN EXAMPLE FROM THE VARISCAN BELT OF SW ENGLAND

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A frequently observed relationship between the orientation of anisotropy of magnetic susceptibility (AMS) ellipsoids in folded low grade metamorphic rocks is an alignment of $K_{max}$ along the intersection of an axial planar cleavage and primary foliations (e.g. bedding). This relationship is interpreted to represent progressive overprinting of primary depositional/compactional fabrics ($K_{min}$ perpendicular to bedding) by a tectonic fabric ($K_{min}$ perpendicular to cleavage). Such composite fabrics are usually oblate in shape with $K_{max}$ typically aligned perpendicular to regional transport directions.

Sandstone and shale beds have been sampled around a single upright, open anticline from the sub-greenschist facies Bude Formation (Cornwall, UK) in order to investigate further the kinematic significance of these relationships. The mean magnetic susceptibility of these rocks is 0.2 x 10-3 SI, suggesting low concentrations of ferromagnetic phases. The mean corrected anisotropy degree is 1.04 with a mean shape parameter of -0.5 (prolate). $K_{min}$ and $K_{int}$ define a girdle distribution striking sub-parallel to the fold axial plane, with $K_{min}$ tending to cluster around the fold axis. $K_{max}$ axes from both limbs of the fold define a cluster with a mean azimuth perpendicular to the fold axis. This arrangement of $K_{max}$ and $K_{min}$ could represent an inverse magnetic fabric of composite primary/tectonic origin. However, this is discounted on the basis of close correlation between the orientation of the AMS and anisotropy of isothermal remanence (AIRM) ellipsoids. A further discrepancy with the commonly observed AMS fabrics in folds is the strongly prolate shape of the ellipsoids.

The consistency of $K_{max}$ orientations irrespective of position within the fold clearly points to a fabric of tectonic origin. Prolate ellipsoids with long axes perpendicular to the fold hinge line are indicative of superimposed stretching at a late stage or post-dating fold formation. Such a situation is consistent with superimposed simple shear documented by the variation in fold attitude on a regional scale, with $K_{max}$ parallel to the regional transport azimuth. For this to be the case, the AMS fabric must represent only the last increments of strain in this area, with earlier primary and fold-related fabrics being entirely obliterated.

## MAGNETOSTRATIGRAPHIC CORRELATION OF MARINE (UK) AND NON-MARINE (EASTERN USA) TRIASSIC/JURASSIC BOUNDARY SUCCESSIONS

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The magnetostratigraphy of the latest Triassic and earliest Jurassic succession (upper Mercia Mudstone Group, Penarth Group and basal Lias Group) exposed at St. Audrie's Bay, west Somerset, has been studied from samples from 145 levels in a 124 m section that includes a candidate GSSP for the base of the Jurassic. Continental red-beds (c. 68 m) in the Mercia Mudstone Group below the Blue Anchor Formation, include three major normal magnetozones. A transition, from continental to marginal marine deposits, occurs in the Blue Anchor Formation which has predominantly reversed polarity, except at the top, in the Williton Member. The largely marine Penarth Group has predominantly normal polarity except near the middle of the Westbury Formation and at the top of that formation and the base of the Lilstock Formation. The marine Lias Group, examined to a level high in the *Psiloceras planorbis* Zone, has normal polarity, except for a minor reversed interval in the basal pre-*planorbis* beds, c. 4 m below the base of the *P. planorbis* Zone. This magnetostratigraphy compares well with a presumed Norian to Hettangian magnetozone sequence in the non-marine Newark Basin succession, eastern USA. The level taken as the base of the Jurassic in both areas is in a predominantly normal magnetozone.

## THE PREDICTABLE ENVIRONMENTAL IMPACT OF MINE WASTE REMOBILISATION; A CASE STUDY

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The historical release of mine waste tailings into the estuaries of Cornwall has led to extensive siltation. The mineralogy of the mine waste retained within the reducing sediment profile is geochemically less reactive and not bioavailable. Recently, an area of mine waste contaminated estuarine sediments have been reworked during minor engineering works, resulting in the sediments being placed above the water table. Subsequent oxidation and alteration of the sediments has resulted in the remobilisation of the mine waste. Individual samples contain >49,000 ppm Cu, >9,800 ppm As, >39,000 ppm Zn, >1,900 ppm Pb and 85 ppm Cd. Sequential leachate experiments showed that with freshwater, the leachate contained 0.34 ppm Cu, 20 ppm As, 102 ppm Zn, 0.1 ppm Pb and 1.02 ppm Cd. Subsequent leaching using an EDTA extraction, which mimics humic acids, resulted in a leachate with 186 ppm Cu, 211 ppm As, 1404 ppm Zn, 699 ppm Pb and 13 ppm Cd. The secondary minerals are dominated by Cu oxides/hydroxides and Cu halide species, including the mineral atacamite. The re-release of the metal mine waste in solution shows that the toxic metals have been made bioavailable.

This mine waste remobilisation was entirely predictable if the land owner had been aware of the sediment geochemistry and mineralogy. The simple action of reworking the sediment and allowing it to oxidise has led to a significant environmental impact. The implication of this case study is that we need to ensure that there is increased awareness by non-specialists of the potential impact of remobilising contaminated sediments. Current environmental legislation related to contaminated land, based upon total metal concentrations, is in our opinion, misguided, in that the mineralogy is commonly neglected but is the most significant factor when assessing the potential for remobilisation of environmental contaminants.