

VALUING GEODIVERSITY FOR CONSERVATION IN DEVON

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Quarries can be important sites for geodiversity, as shown by a recently completed study in Devon. However, the quality of geodiversity is variable; it can be better or worse than similar geodiversity seen in natural or other man-made rock exposures. There are established procedures for determining geological SSSIs and RIGS; but these do not enable the relative quality of geodiversity to be established. In this presentation, a procedure is proposed with a set of generic parameters for measuring the quality of geodiversity in quarries. The result is a numerical tool called the geodiversity value measure intended for use by quarry companies, planners and others as an aid to decision-making on geoconservation issues. The geodiversity value measure has three parts. The first is an audit of geodiversity using geological interest categories as a basis for scoring. The second part is an assessment of the value of the geodiversity to the community in terms of its scientific, educational, and historical, cultural and aesthetic qualities. The third part is an ecological value, interpreted as an assessment of how the geology can be used to understand the ecology of habitats within the landscape of the locality. The geodiversity value measure has been discussed at length at a focus group meeting of stakeholders in geodiversity, and the initial proposals modified. The modified proposals are discussed, and a preliminary assessment given of their application in two contrasting quarries in Devon.

THE GEOLOGY AND GEOTECHNICAL ASPECTS OF DEVONPORT DOCKYARD AND THEIR IMPLICATIONS FOR REDEVELOPMENT AND NEW BUILD

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Devonport Dockyard is situated on the Hamoze stretch of the Tamar Estuary near Plymouth, Devon. The slates and slaty mudstones of the Saltash and Torpoint formations and the more recent Quaternary deposits of alluvium dominate the geology of Devonport Dockyard. The dockyard dates back to 1691 and has undergone several periods of redevelopment, firstly at the turn of the 1900s, then in the 1970s and more recently from 1990 to the current day.

A large number of challenges have faced redeveloping Devonport Dockyard. These include: redeveloping docks which date back to Victorian times; the complex geology and the discovery of fault lines and since becoming a nuclear licensed site it has come under the regulation of the nuclear installations inspectorate meaning it has to meet their guidelines including structures that can withstand a 1 in 10 000 year earthquake (which equates to 0.25 a).

This paper highlights the problems and issues faced during construction and redevelopment quoting examples, including: the nuclear transfer route, the building of the low level refuelling facility and the construction of 9 Dock. Furthermore, the paper illustrates the rigorous maintenance regime that is done using ground anchorages as an example to ensure that the docks are maintained to required standards and safety limits.

A REVIEW OF THE STRATIGRAPHY AND AMMONITE FAUNAS OF THE CHARMOUTH MUDSTONE FORMATION (LOWER JURASSIC, MID LOWER SINEMURIAN TO BASAL UPPER PLIENSCHACHIAN) OF THE WEST DORSET COAST, SOUTH-WEST ENGLAND

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The 'Lower Lias' mudrocks of the Charmouth Mudstone Formation along the West Dorset coast are famous for their ammonite faunas, which range in age from mid Lower Sinemurian (Semicostatum Chronozone) to basal Upper Pliensbachian (basal Margaritatus Chronozone, Stokesi Subchronozone). However, the succession includes significant non-sequences, and as certain other intervals yield only crushed and relatively poorly preserved material, much of the sequence of ammonite faunas has remained poorly known. Therefore, this review, brings together recent records from the area to establish a revised framework for the correlation of the Charmouth Mudstone Formation in West Dorset, within contemporary standard zonal frameworks. Within the formation the following members are recognised and regional correlations discussed: Black Ven Member *nov.* (including the Shales-with-Beef and Black Ven Marls *aucct.* – Lower Sinemurian, Semicostatum Chronozone, Sauzeanum Subchronozone to Upper Sinemurian, Raricostatum Chronozone and Subchronozone), Stonebarrow Marls Member *nov.* (formerly Belemnite Marls – Lower Pliensbachian, Jamesoni Chronozone, Taylori Subchronozone to IbeX Chronozone, Luridum Subchronozone) and the Seatown Marls Member *nov.* (formerly Green Ammonite Beds – Lower Pliensbachian, Davoei Chronozone, Maculatum Subchronozone to Upper Pliensbachian, Margaritatus Chronozone, Stokesii Subchronozone).

PETROLEUM GEOCHEMISTRY OF THE WESSEX BASIN (DORSET, UK)

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The Wessex Basin contains two major petroleum plays: the Triassic Sherwood Sandstone and the Jurassic Bridport Sands. Produced oils and oil seeps have been analysed by gas chromatography-mass spectrometry to provide biomarker data to determine source rock facies and maturity. Principal component analysis clearly distinguished the Sherwood and Bridport plays, the latter being of consistently lower source rock maturity, and interpreted as reflecting earlier oil generation in the basin.

Significantly, none of the produced oils in the Wessex Basin are biodegraded, despite their low reservoir temperatures (40-65°C). This is explained by the concept of palaeopasteurisation, whereby the reservoirs were previously buried to depths where the temperatures exceeded the temperature (c. 80°C) at which hydrocarbon-degrading bacteria are killed. Although subsequent uplift in the Tertiary led to cooler temperatures, the reservoirs had been effectively pasteurised and have clearly not been re-colonised by hydrocarbon-degrading bacteria. Interestingly, a few oils show some evidence for biodegradation, possibly due to shallower burial, and consequently inefficient palaeopasteurisation of the reservoir. This interpretation indicates that reservoir burial history reconstructions may be important to give pre-drill predictions of biodegradation in other prospects in the Wessex Basin.

LARGE-SCALE SOUTHWARDS FACING STRUCTURES IN THE LOOE BASIN (LOWER DEVONIAN), SW ENGLAND

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The Looe Basin (Pragian-Eifelian) formed along the southern margin of the Devonian continental shelf in SW England, to the north of the deep marine Gramscatho Basin. Our ongoing work has identified a substantial and little described ~5 km wide zone of consistently southwards-facing primary folds, that crops out to the west and north of St Austell Bay, along the southernmost part of the basin. A gently inclined 100 m-thick shear zone within the Polglaze Formation forms the southern boundary between the southwards-facing primary folds and the northwards-facing primary folds of the Grampound Formation (Gramscatho Basin). We consider that the southwards-facing primary structures were generated during D₁ inversion by the southerly-directed expulsion of the infill of the southernmost half-graben of the Looe Basin. To the east, in a dextrally displaced block between the Coombe Hawne and Portnadler faults, large-scale southwards-facing primary folds are also present. These folds we correlate with those further to the east around Rame Head and north of the Start Complex, and those to the west around Perranporth. We consider that these southwards-facing structures were generated during secondary (D₃) backfolding of initially northwards-facing primary structures in response to the post-convergence extensional reactivation of E-W trending basement faults.

CLIFF STABILISATION AND MANAGEMENT AT BEER, EAST DEVON

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A series of cliff falls occurred during January – March 2001 at Beer, East Devon, which wrecked some beach huts and cafes. Fortunately no people were injured but it was necessary to close the coastal footpath and parts of the beach from public access. From a range of options identified and evaluated, a relatively cost effective interim solution was undertaken, rather than permanent closure or high cost full-scale engineering works.

The stabilisation works involved some re-profiling and extensive reinforcement with rock nets and rock bolts, and also drainage measures, safety fences and reinstatement. The overall plan also involves regular inspections and review as part of ongoing management of the cliffs, aiming to balance the inherent risks posed by steep cliffs with the need to maintain public access at reasonable costs to the public coffers and the environment.

The project has been undertaken for East Devon District Council, with an overall value in the order of about £0.3 million. The inspections, assessments, engineering design, works supervision and project management have been undertaken by David Roche GeoConsulting.

The paper presents a case study, which reviews the nature and extent of the cliff instability, the range of possible options, and the cliff reinforcement works and management scheme eventually undertaken.

UPDATE ON CURRENT MAPPING AROUND NEWQUAY

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Ongoing mapping in the Newquay District, within the parautochthon of the Variscan in southwest England, has already produced some interesting results. The northern part of the sheet is occupied by sediments belonging to the Dartmouth Group (dominated by purple and green mudstone), the Meadfoot Group (sandstone, mudstone and some limestone), and a unit of dark slaty mudstone with some siltstone and sporadic sandstone. The age of this latter rock unit is as yet unknown, but at its northern boundary would appear to lie conformably on rocks attributed to the Meadfoot Group. In the southern part of the sheet, rocks belonging to the Grampound and Porthtowan formations – dominantly comprising olive-green silt/sand and grey/green turbidite sediments, respectively – are present. The current working hypothesis is that the 'northern' sediments (Dartmouth, Meadfoot, dark mudstone) are formed from sediments deposited in the Looe Basin, whilst those in the southern part of the sheet (Grampound and Porthtowan formations) relate to sediments from the Gramscatho Basin. Determination of ages for the Grampound Formation and dark slates, further study of field relations and geochemical analyses should allow the nature of these relations to be constrained.

Deformation in the area, determined to have occurred in three phases, is regionally related to the closure of the Gramscatho and Looe basins from the south (D₁ and D₂) and the later collapse of the orogen (D₃). The concentration of D₃ structures around Ligger Point, and to the east where small quarry exposures occur, is likely to be controlled by basin architecture. During the extensional phase of the Variscan orogen, granite intrusion was widespread in the region including, in the Newquay district, a poorly-exposed granite ridge extending from St Agnes Beacon to Perranporth (Dines, 1956). ENE-WSW trending hydrothermal veins associated with this body dominate the mineralisation of the area and some greisen development is seen. Tin-bearing veins of the St Agnes region include examples of early tourmaline-quartz-cassiterite assemblages and later polymetallic (Sn-Cu-Zn-As-Pb) veins.

BUYING FOSSILS? LET THE BUYER BEWARE!

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Most fossil require 'preparation' of some sort before going on public display, or being sold to collectors. Matrix needs to be removed, shaley samples may need to be stabilised, broken bones need to be stuck together, etc. Even some of the classic specimens in our museums have often been 'completed' or 'painted' before display. A relatively recent phenomenon, however, is the wholesale and systematic 'improvement' of fossils, especially of trilobites from North Africa. Examples shown were all from Europe's biggest mineral and fossil fair at Munich. Although these may be seen by collectors to be cheating or fraud, those who dig out the fossils regard it as common sense: "Who would want to buy an incomplete trilobite, when I can so easily 'repair' it?". There are also outright 'frauds': resin replicas stuck on to limestone bases with the joint scuffed over to become 'invisible'.

ENGINEERING STRATIGRAPHY OF THE LOWER LIAS OF THE GLASTONBURY DISTRICT

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In the Glastonbury district, the Lower Lias is poorly exposed and is often hidden beneath the alluvium of the Somerset Levels. Consequently, it is poorly known and not subdivided on published maps. This is of practical concern, since the wide variation in facies controls not only the engineering properties of the Lower Lias, but also influences the most appropriate means of site investigation.

An engineering stratigraphy for the area is described, and a provisional map presented. These are based on over 50 commercial site investigations in the area, including many boreholes through the alluvial cover, and on other published and unpublished data. The expected division into a lower limestone-bearing sequence and an upper limestone-free sequence is present. The limestone-bearing sequence is further sub-divided on the basis of thickness and abundance of limestone beds. The limestone-free sequence is subdivided on the basis of the plasticity of the clays. The correlation of the engineering stratigraphy with the known stratigraphy from the Somerset and Dorset coasts and the Burton Row borehole is discussed.

EROSION AND FAILURE OF AN APRON OF DEVENSIAN HEAD ON THE NORTH COAST OF JERSEY, CHANNEL ISLANDS: TECHNIQUES OF INVESTIGATION, RESULTS, AND SIGNIFICANCE FOR FUTURE DEVELOPMENT IN AN ENVIRONMENTALLY SENSITIVE AREA

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The intended development of a former hotel site on a shelf of Devensian head within metres of a 15 to 20 m steep drop to tidal rocks of the bay below, required a detailed geological and geo-engineering appraisal of the site and its situation. Accurate measurement of levels and locations were provided by a specialist topographical survey. Comparison of this cliff with other north coast embayments enabled the establishment of likely profiles of the bedrock/head interface between the beach and the bedrock above the hotel. A survey of historical data, centering on old photographs, allowed the estimation of erosion rates over the 110 years; other historical evidence, deriving mostly from old cliff edge field banks, added an extra dimension to the erosional history of the area taking the record back probably into the 18th century. In addition to the varied erosional features identified in the historical studies, failure of the cliff over time was observed to relate to a series of collapses on arcuate slip planes, the radii of which are linked to head thickness. Variations in the composition and texture of the head parallel and normal to the solid rock cliff line were determined in detail locally but more generally in qualitative terms; some limited borehole information was available.

A BASIS FOR DEVELOPMENT OF A QUANTITATIVE RISK ASSESSMENT METHODOLOGY FOR COASTAL SLOPES IN CORNWALL

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Previous reporting of an investigation into the risk posed by coastal instability along the Cornish coastline, presented at the January 2003 Ussher meeting, provided a framework for development of a qualitative risk-based approach for coastal instability assessment. More recent work has focussed on refinement of the qualitative methodology, taking into consideration both hazard consequence and likelihood of particular slope failure mechanisms occurring along specific sections of coastline. This has resulted in a semi-quantitative ArcView-based (geographical information system) framework for evaluation and subsequent highlighting of high-risk locations in Cornwall. Risk-maps have been created to improve visualisation of key data and, importantly, highlight high-risk locations for further, more detailed, quantitative risk evaluation.

The subsequent quantitative analysis has concentrated on two main aspects associated with the potential for coastal instability: risk to people (beach-users) and risk to property (land loss). Quantitative evaluation of risk to people utilized a rock fall model, whereas evaluation of risk to property was based on the impact of simulated coastal recession rates. Examples of both categories are presented to highlight areas that pose the greatest risk from coastal instability in Cornwall. The ArcView-based approach provided a means to rapidly assimilate the key issues, and the spatial variation of the range of risks identified. This type of analysis has important implications for management of the coastal zone within Cornwall.

THE GEOCHEMICAL SIGNATURE OF MINE WASTE CONTAMINATION WITHIN SALTMARSH SEDIMENTS OF THE ERME ESTUARY, SW ENGLAND

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In this study the concentration of selected trace metals (Cu, Pb and Zn) from saltmarsh sediments have been measured in order to assess possible historical sources of pollution within the Erme Estuary. The River Erme is one of several small south Devon rivers that drain the hills of Dartmoor. Although the Erme Estuary has remained largely unaffected by industrialisation (compared with for example the Tamar and Plym estuaries), within the catchment a number of small silver-lead-copper mines were in operation in the 1800's. Five cores examined reveal similar geochemical profiles. Particularly an increase of lead at ~40 – 20 cm depth is observed, reaching maximum values of 390 ppm. Zinc shows no significant down core increase. The analysis of copper also reveals an increase in concentrations at ~40 – 20 cm depth. Hence the geochemical analysis of the saltmarsh sediments gives a fairly robust chemostratigraphic scheme and the likely sources of mine waste can be pinpointed within the catchment. Based upon reference to the historical mining record of these mines chemostratigraphic dating of the sediments provides a model consistent with published estimates of saltmarsh accretion rates and sea level rise.

A LARGE-SCALE GEOLOGICAL SURVEY OF THE NEARSHORE AREA AT LYME REGIS, DORSET

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During the past 10 years West Dorset District Council (WDDC), in its role as the coast-protection authority, has carried out detailed geological, geotechnical and geomorphological studies of the onshore and offshore areas adjacent to Lyme Regis. The primary aim has been to enable long-term engineering solutions to be found to the inter-related problems of landslip and marine erosion that threaten the sea front. An important part of the engineering remit is to be able to predict the consequences of alternative stabilisation schemes in order to minimise the impact on the local geological exposures and the related environments. Taken together, the cliffs on either side of the built-up area form the type section of the Blue Lias Formation, and are an integral part of the Jurassic Coast World Heritage Site. In addition, landslips that extend into the built-up area include important biological habitats that are protected by legislation.

In order to understand the distribution of the lithologies and geological structures, large-scale (up to 1:1000) geological maps of the intertidal and adjacent landslip areas have been prepared using a combination of traditional field surveys and aerial photography supplemented by laser-telemetry and a seismic-reflection survey. The results are summarised in a 1:5000-scale geological map of the coastal area between Devonshire Head and Charmouth, and a revised generalised vertical section for the stratigraphy of the area.

AN INTEGRATED SEDIMENTOLOGICAL AND ICHNOLOGICAL ANALYSIS OF AN ARENACEOUS UNIT IN THE MERCIA MUDSTONE GROUP, EAST DEVON, U.K.

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The Mercia Mudstone Group exposed on the east Devon coast consists of about 450 m of predominantly red mudstones and associated evaporites. A more fluvial interval of laminated mudstones in the middle part of the group (the Dunscombe Mudstone Formation) contains thin interbeds of calcareous siltstone/sandstone. A detailed analysis of the sedimentology and ichnology of the thickest of these arenaceous units (the Lincombe Member) has revealed complex internal lateral facies changes. The member is exposed intermittently over a distance of 1.75 km, within which it thickens from 1.5 to 4.5 m in an easterly direction. The more easterly exposures show bioturbated, interlaminated clayey siltstones and very fine-grained sandstones thinly interbedded with mudstones. They are thought to represent a lacustrine depositional environment. The presence of colonial chlorococcalean alga (G.A. Booth *pers. comm.*, 2004), conchostracans, and an impoverished ichnofaunal suite are suggestive of fresh water. Rooted red clays, some with evidence of pedogenic alteration and a paucity of bioturbation, occur towards the top of the member and suggest an overall upward drying of this sequence. Several episodes of probable fluvial input are well developed at the western end of the outcrop of the member. A relatively diverse, but wholly continental ichnofauna, are recorded from these sediments.

THE USE OF REGIONAL PLANT UPTAKE STUDIES AND SEQUENTIAL EXTRACTION DATA IN THE QUANTITATIVE ASSESSMENT OF HUMAN HEALTH RISKS ASSOCIATED WITH SOIL ARSENIC IN THE SOUTH-WEST OF ENGLAND

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In the derivation of the soil guideline value for arsenic, the EA/DEFRA (2002a) assumed a generic value for the soil to plant concentration factor for both root and leafy vegetables of 0.009 mg/kg dw plant/mg/kg dw soil. The basis for the use of this figure relies on research undertaken in the Netherlands for agricultural soils (RIVM, 2001). The RIVM study was developed solely for use within the CSOIL model.

A number of regional studies have been carried out that are directly applicable to the south west of England, including those of Xu and Thornton (1984) and Warren *et al.* (2003). The data set reported by Xu and Thornton (1984) is comparable in size to that used by RIVM (2001). A site specific soil to plant concentration factor using regional data within the context of current UK risk assessment guidance (EA/DEFRA, 2002b) is developed.

The SNIFFER (Ferguson *et al.*, 2003) methodology is a tool to develop site specific assessment criteria to help assess the quantitative risks of long term human health from exposure to contaminated soils. It can be used to accommodate site measurements of both bioaccessibility and soil to plant concentration factors. Modification of the bioaccessibility term based, for example, on the use of PBET results, alone will only achieve an increase in soil arsenic to 77 mg/kg even if the soil arsenic is completely non bioaccessible. This is because the bioaccessibility term only affects the direct and indirect ingestion of soil and does not address the soil to plant concentration factor. With decreasing uptake of arsenic through direct or indirect ingestion the site grown vegetable pathway will dominate and this alone will limit the safe soil arsenic term.

Sequential extraction data for soils can be used to compare the physiochemistry of different soils and to demonstrate similarity in physiochemical behaviour of different soils. Sequential extraction data are presented for different soils within the study area of Xu and Thornton (1984) and has been used to compare the physiochemical behaviour of other soils in the south west of England over the same geological outcrop. The argument is put forward that sequential extraction data can be used to assess the applicability of the Xu and Thornton (1984) derived soil to plant concentration factors to soils outside the immediate study area.

**MODELLING COASTAL MORPHOLOGY
AND ITS EVOLUTION**

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The coastline has been 'engineered' for many centuries, initially for the development of ports and maritime trade or fishing harbours to support local communities. The value of attempting to retain beach material, whether for sea defence, coast protection or recreational use has been recognised for some time. With improving understanding of how our coastlines evolve has come a realisation that coastal defence and management is better done at a regional, rather than a parochial basis. However, many of the processes that affect coastal evolution cannot be forecast accurately. This lecture detailed several of the main problems in forecasting coastal evolution and described some recent advances.