Geology Matters

The Newsletter of the Geological Survey of Ireland
Nuachtlitir Suirbhéireacht Gheolaíochta Éireann
Issue No. 4, Spring 2006

Welcome to the first issue of Geology Matters for 2006. In this issue our featured section is Quaternary Geology and Geotechnical where their work varies from Quaternary mapping to the mapping of sand and gravel deposits, and from the mapping of landslides to the representation of underground Dublin. In a feature article by Dr. Joanna Wright of the University of Colorado at Denver, Joanna describes her fascinating work with dinosaur footprints. There is the usual blend of articles on GSI activities and events and the Director's Discourse which introduces the International Year of Planet Earth. Following up on our earthquake stories in earlier issues we have a short piece on the recent 'Bray earthquake'.

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The start of the New Year has been a busy one for the GSI, with the commencement of a number of new projects. The Groundwater Section started the ball rolling early with the Cavan Groundwater Protection Scheme (GWPS) in December and has also started a similar scheme for Galway in February. Sonja Masterson will carry out the work on the Cavan scheme with Eamonn O'Loughlin, while Robbie Meehan will carry out the Galway work. This will bring the total number of schemes to sixteen.

New projects in Minerals Section include a Historic Mine Site Inventory and Risk Categorization project, in conjunction with Environmental Protection Agency and the Exploration and Mining Division of this Department. The project will document the features at our historic mine sites, identify any environmental hazards and carry out a risk categorization of each of the sites studied. For the project we welcome back Vincent Gallagher and Phelim Lally. Another Minerals Section based project sees the GSI collaborate with the Office of Public Works (OPW) in attempting to identify the source of stone used in some of the buildings and monuments in the care of the OPW. For this project Jason Bolton will be employed for the next 18 months. Funding has also been received for a pilot airborne geophysics survey. Work will be carried out at up to five locations and will use the same airborne technology as the recent TELLUS survey carried out by the GSNI (see **Geology Matters No. 3**). This will support the work, not only of the Minerals Section but also Bedrock, Groundwater and Quaternary Sections.

The Marine and Geophysics Section are proud to commence Phase II of the highly successful Irish National Seabed Survey following news of an exchequer allocation of €4 million for 2006. This phase, entitled INFOMAR, is a joint venture with the Marine Institute and extends surveying into the near shore environment (<50m water depth). Read more about this exciting project in this newsletter.

We also welcome Mr. Martin Brennan as Assistant Secretary with responsibility for the GSI. Mr Brennan previously had responsibility for the GSI when it was part of the Department of Transport, Energy and Communications, at the time funding for INSS was secured. Along with the GSI, Mr. Brennan's responsibilities include the Exploration and Mining Division, the Petroleum Affairs Division, Inland Fisheries and Marine Leisure/Research & Tourism.

DIRECTOR'S DISCOURSE
International Year of Planet Earth

The year 2008 was proclaimed by the UN General Assembly last December as the International Year of Planet Earth (IYPE). What does this mean in practice and does it have any relevance for Ireland? The answer to both parts of this question is quite a lot actually!

There is a general recognition that geoscience has slipped relative to other sciences in recent decades. It does not feature as prominently in the media, it is not seen as being relevant to the needs of modern society and, crucially, its level of funding has not kept pace with that of other sciences. IYPE is seen as a powerful tool to help remedy this situation and to demonstrate how society can benefit from geoscience's accumulated knowledge as well as from the impact of future investment. IYPE will comprise two important programmes.

The Science Programme comprising ten broad themes has been developed as the core of IYPE. These themes are: Groundwater, Climate, Earth & Health, Deep Earth, Megacities, Resources, Hazards, Ocean, Soil and Earth & Life. An attractive brochure has been produced for each theme, one of them sponsored by GSI, in both printed and electronic forms. Scientists around the world will be encouraged to become involved in projects on these themes.

The Outreach Programme will be vital in delivering the messages of IYPE to the widest public and will operate mainly at national level. Activities are likely to include educational materials, competitions, media programmes, art commissioning and support for scientists from weaker economies. Brochures and leaflets explaining the programme will be widely circulated and organisations and individuals will be invited to submit project proposals at both national and international levels.

At international level IYPE will be registered as a not-for-profit corporation under the patronage of UNESCO, the International Union of Geological Sciences and other relevant scientific organisations. It expects to raise a budget of $20 million to manage what will in effect be a triennium (2007-2009) and the budget will be divided equally between the science and outreach programmes, with only 5% devoted to administration.

Ireland, as with all participating countries, will shortly establish a National Committee for IYPE which will have a broadly based representation of the geoscience sector. The Committee will be responsible for developing a national programme of activities which will address the key issues outlined in the set of science brochures and generate awareness of the value and relevance of geoscience knowledge to society. It will raise sponsorship to support this activity as well as to contribute to international efforts.

In due course the National Committee will no doubt have its own website. Meanwhile if you wish to find out more about IYPE you are invited to visit www.yearofplanetearth.org.

FEATURED SECTION – QUATERNARY AND GEOTECHNICAL SECTION

The Quaternary and Geotechnical Section carries out basic mapping and database activities on the Quaternary sediments across the country. Since approximately 95% of the country is covered by these sediments the Section has a very important role to play in the Survey. There are four articles in this issue of Geology Matters on the work of the Section. Firstly we have a review article by the Quaternary Head of Section Dr. William Warren on the history of Quaternary Mapping in the GSI. Then we have an article on the Availability of Digital Quaternary Data from the GSI by Michael Sheehy. Next there is an article by Dr. Ronnie Creighton (head of the Geotechnical part of the Section) and Beatriz Mozo on the geology of Dublin based on the geotechnical records held by the Section. Finally we have an article relating to geohazards, and specifically landslides in the Breifne area of the country by Xavier Pellicer.

Quaternary Geology in the Geological Survey of Ireland

William P Warren

When the Geological Survey of Ireland was founded in 1845, it was intended to map simultaneously the Quaternary and the bedrock geology. However within a few years it became clear that this was a bigger undertaking than had been anticipated and geologists were instructed to cease sampling and mapping out the Quaternary units. Notes were to be taken of obvious Quaternary features where convenient, but otherwise the main effort was to go into the bedrock mapping exercise. Although the earliest printed county maps indicated “Tertiary Gravels” the first of the main series, produced in the 1850s contained no Quaternary information whatsoever. After it was pointed out that the little demand there was for the Survey's maps was mainly from estate owners anxious to have a depiction of the extent of the "drift", a change of policy was instituted and geologists were instructed to mark the Quaternary or "drift" on the 1:63,360 maps before they were sent to the engravers. It is clear from the manuscript field maps that this continued to be done, for the most part, on the basis the geologists' sketchy field notes together with and the indications of peat and alluvium on the Ordnance Survey 1:10,560 maps.

Thus, despite this clear demand, nothing was done to change the nature of the mapping exercise until the initial bedrock survey had been completed in 1890. In 1897, James Kilroe made the case for a "drift" map of Ireland, which would have an economic rather than a "purely geological" focus. However, when "drift" mapping began in 1901 it was limited in extent to the districts surrounding the chief cities, and in content to distinguishing the chief lithological units. Maps and accompanying memoirs of the districts around Dublin, Belfast, Cork, Derry and Limerick were produced between 1902 and 1908. The Killarney and Kenmare district was mapped between 1912 and 1914 and a special "drift geology" map of was published in 1922, the memoir following in 1927. These maps were all published in colour.

In the 1920s some Quaternary mapping was carried out adjacent to the lower reaches of the Shannon in relation to the Ardnacrusha hydroelectric scheme, and in the 1930's 1:63,360 sheet 120 (Blessington area in County Wicklow) was mapped and reached printer's proof stage, but was not published. In the 1940s parts of Monaghan and Cavan were mapped at the 1:10,560 scale, and in the 1960s Counties Limerick, and Carlow were mapped complementing the Soil Survey mapping that was being done at that time.

In the late 1960s a Quaternary Section was established in GSI with the objective of mapping the Quaternary geology of the State. In the 1980s the section took responsibility for geotechnical matters and became the Quaternary and Geotechnical Section. Permanent staffing levels in this section never exceeded four, was reduced to one for a substantial period, and has averaged no more than two. Thus, even with at times substantial temporary staff input, progress has been slow.

Nevertheless from the late 1980s on, significant progress was made by means of arrangements with universities and external contracts. During this time Counties Clare Kilkenny, Laois, Louth, Meath and Wicklow (remapped), together with substantial parts of Kildare, Longford, Mayo, Offaly and Westmeath, and parts of County Roscommon were mapped. These maps were designed to meet the requirements of a broad range of client areas including: the aggregate extraction industry, agricultural soils, groundwater resource and protection, resource and environmental planning, civil engineering and geotechnics, mineral exploration, and education and leisure.

Most of the mapping carried out since the early 1960s has been digitised and there is an ongoing programme of digitising all archival Quaternary data held by the GSI. However, most of these data were recorded in the nineteenth century and are of very poor quality. Figure 2 in the article following, by Michael Sheehy, illustrates the availability of digitised maps and reports.

Available Digital Quaternary Geology Data in It's Various Incarnations

Michael Sheehy

The Quaternary & Geotechnical Section holds digital Quaternary data for most of the country. All data has been compiled for use at the scale of 1: 50,000 but these data are held in a variety of formats, at different levels of confidence and coherency, and have been digitized using an assortment of techniques over more than a decade.

Figure 1. Green areas correspond to digital datasets held by the Quaternary Section

The datasets can be divided into three levels of confidence:

- Modern reconnaissance mapping
- Older reconnaissance mapping
- Desk compilation of very old, chiefly spot, data

Modern reconnaissance mapping methodology include office based techniques such as desk compilation of existing datasets, literature reviews, photogrammetry and satellite image interpretation, geostatistical modelling and sample analysis. The field portion of the exercise includes drilling, sampling and geophysical and GPS surveying. The process is iterative, with the field and office based parts combining, as an accurate model is built up over the cycles, establishing to a high degree of confidence the nature and extent of the Quaternary features in the area of interest.

Modern Quaternary reconnaissance mapping products are amongst the most sought after products by the Geological Survey of Ireland's (GSI) clients. These data are created and compiled with the strengths of GIS applications in mind and they conform to exacting topological standards. The Quaternary and Geotechnical Section is constantly striving to improve and refine the techniques used, and thus results gained. The latest instalment in the drive to improve standards and develop new methodologies has led to a partnership with NUI Maynooth Geophysics Section with a PhD on the identification and characterization of Quaternary sediments using geophysical techniques. The main constraint on this programme is a crippling lack of staff.

The Quaternary Section has a wealth of older paper-based reconnaissance information that has been mapped and compiled by geologists over the past several decades. These data have been compiled for various projects (usually on a county basis) and digitized into CAD or GIS environments using tablet digitizing and more recently heads up digitizing. They will serve as a very solid platform for the development of the modern Quaternary reconnaissance mapping products in the future. These products are in demand where modern Quaternary reconnaissance mapping products do not exist.

The third category of datasets held by the Quaternary Section hails, mainly from, the 19^{th} century work of the survey. This data is extremely variable. At best it gives unparalleled insights into our, now built over, urban environments. Normally, however, the data is widely dispersed point information. Advances in Quaternary science since then, such as abandonment of the "Great Flood" theory, make some of this data questionable. It is nevertheless an enduring credit to the people who traversed the country and mapped these features that the data they gathered is still the best data that the GSI holds for some areas.

Most of the older reconnaissance mapping data and a good part of the very old data has been digitized but staff shortages have delayed the digitizing programme. Co. Tipperary data is currently being compiled and this is due for completion at the end of May.

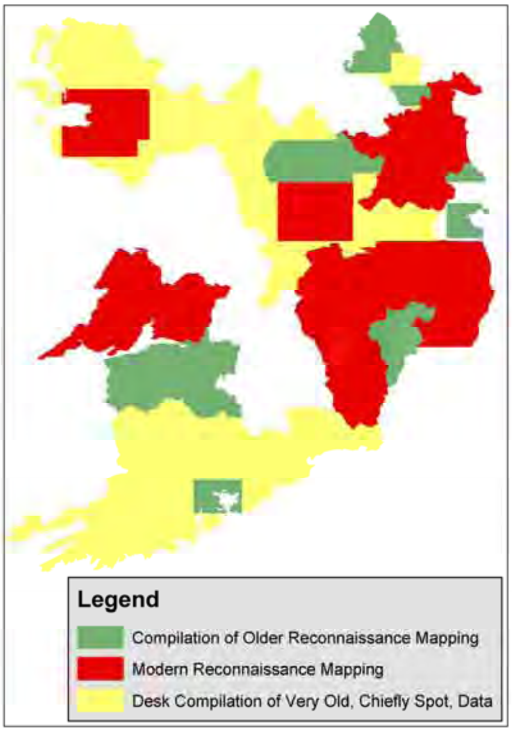


Figure 2. Mapping levels

Breifne Area Landslides Susceptibility Mapping

Xavier Pellicer

The implementation of a methodology for systematic production of landslide susceptibility maps hasn't been embraced yet in Ireland. The Bréifne Area, located in North West Ireland and covering an area of 2129.7km^2 within the Republic, was chosen as a suitable test area for this purpose.

Several digital datasets available were tested: orthophotography, Landsat ETM+ imagery, and Digital Elevation Models (DEM) at 20 and 50m resolution. Colour and black and white (B&W) orthophotography was deemed to be the most suitable due to their high spatial resolution. The B&W orthophotography was combined with a DEM at 20m resolution using ©Fledermaus software to identify and classify the landslide occurrences in the area. Digital stereophotography was also employed for certain areas.

Landslides mentioned in the literature were analysed using 3D orthophotography to recognize its signature and to identify elements that would assist the classification of similar events. The work was focused in areas with slopes greater than 15° and the region systematically surveyed to identify, classify, locate, orientate and measure landslide events. ArcGIS software was used to digitise the head of the event as a point feature. A line from this point to the toe of the landslide was digitised to recognize the total length of the event and its orientation. A total of 694 landslides were identified and classified into 17 subgroups. These were subsequently grouped into 4 main landslide types: bedrock slides, peat slides, falls and flows.
A total of 52 landslides were visited and described during fieldwork carried out to verify the methodology. The following parameters were recorded when available: morphological setting, dimensions of the event, geological setting, impact on the landscape and the infrastructure, remedial measures taken and climatic conditions during event. The remote sensing based classification was revised and contrasted with fieldwork descriptions. Following the fieldwork 30% of bedrock slides and 50% of peat slides were reclassified. The fieldwork was essential to properly categorize and catalogue land movements previously identified using remote sensing techniques.

The literature review and the fieldwork observations reveal that conditioning factors triggering landslides differ depending on the landslide type. Each of the landslide types mentioned above was assumed to encompass similar conditions to landsliding. Six datasets were developed as thematic maps for the area and considered as triggering factors: bedrock type, soil parent material, land cover, slope, aspect and elevation. Statistical analysis was used to determine the influence of each triggering factor on each landslide type. The percentage of a landslide type occurring in a class within a triggering factor was assigned as the weight controlling the susceptibility to landsliding in areas covered by that class (Fig. 3).

Four susceptibility maps were produced, one for each landslide type. The triggering factors expressed as raster thematic maps were reclassified according to the weights mentioned above (e.g. bog & heath was reclassified to 56 for bedrock slides, to 82 for peat slides, to 38 for flows, and to 42 for falls - Fig. 3). The reclassified pixel values of the six thematic maps were summed using the Spatial Analyst extension of ArcGIS. On the resulting susceptibility maps high pixel values indicate high susceptibility to landsliding and low pixel values represent low susceptibility. Maps were divided into 7 levels of susceptibility to landsliding ranging from extremely high to extremely low values.

Error assessment was also performed to analyse the correlation between landslides mapped and susceptibility values where these events occur (Table 1). An example of the landslide susceptibility map for bedrock slides is displayed in Map 1. Integration of additional conditioning factors such as rainfall or structural geology might improve this correlation. The methodology used during this project allows the incorporation of new datasets (triggering factors) to derive more accurate landslide susceptibility map outputs.

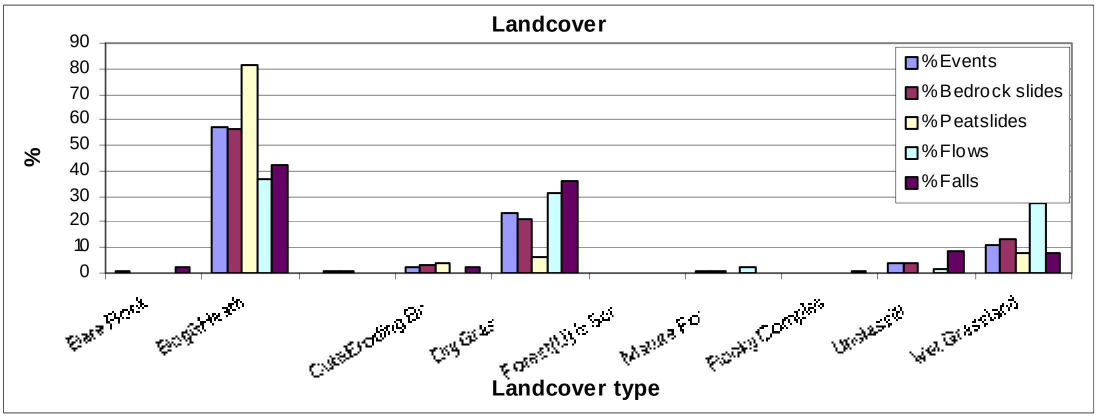
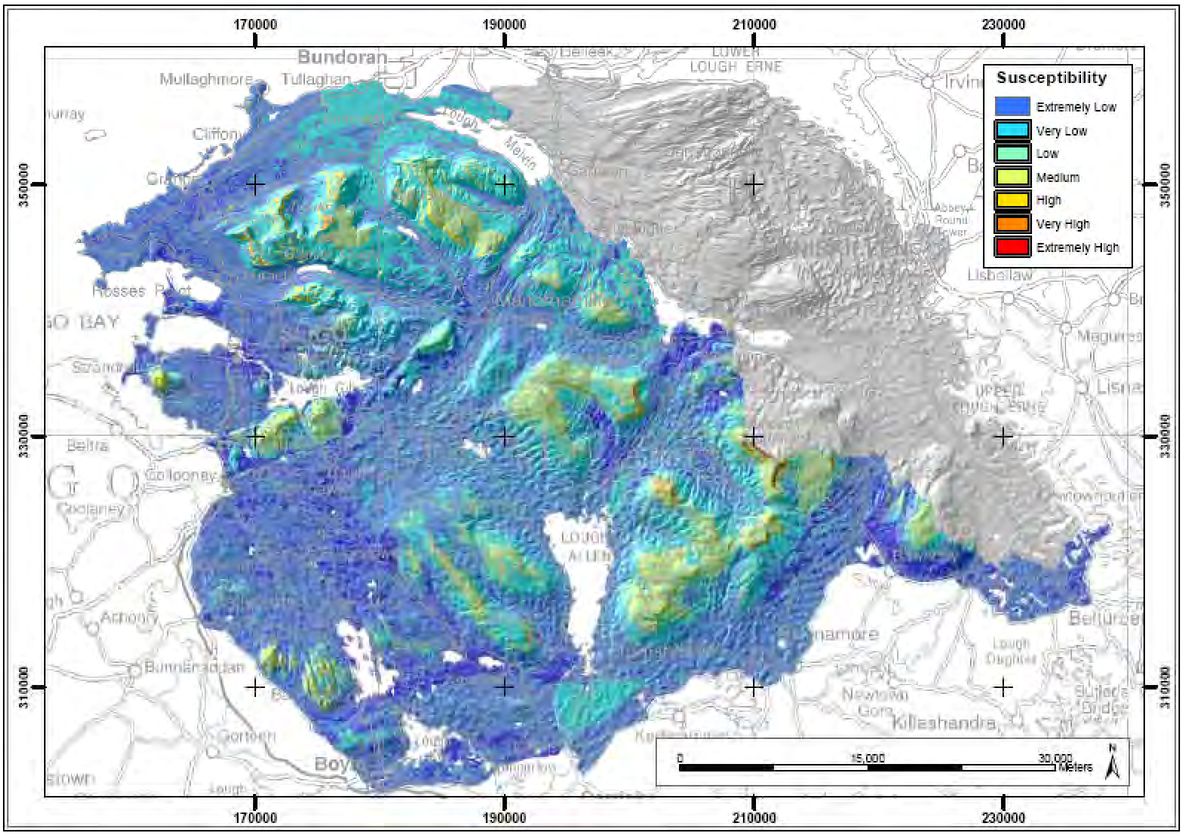


Figure 3. Percentage of landslides by land cover type

Susceptibility	% Bedrock Slides	% Peatslides	% Flows	%Falls
Extremely High	8.82	19.01	8.97	9.22
Very High	18.63	15.29	19.23	4.96
High	32.35	36.36	23.08	35.46
Medium	36.27	29.34	41.03	47.52
Low	3.92	0.00	7.69	2.48
Very Low	0.00	0.00	0.00	0.00
Extremely Low	0.00	0.00	0.00	0.35

Table 1. Error assessment. Percentage of events mapped contained within each susceptibility category



Map 1. Landslide susceptibility map for bedrock slides

SUBSURFACE GEOLOGY OF CENTRAL DUBLIN

Ronnie Creighton and Beatriz Mozo

Transport 21

The subsurface geology of central Dublin is very important to the implementation of the recently announced Transport 21 initiative. A major expansion of Dublin's transportation system is planned and a major element in it is the construction of underground rail lines. This will require extensive tunnelling in the city centre area in particular. The nature of the subsurface geology is crucial to the engineering design and therefore to the ultimate cost of the project.

Boreholes in Dublin

Information on the subsurface is largely dependent on data derived from boreholes. Over many decades there has been extensive drilling in Dublin city centre. A key parameter is the depth to bedrock. Much of the earlier drilling was to relatively shallow depths which often did not meet bedrock, whereas in recent years the construction of larger buildings and the requirement for deep basements has meant that drilling has gone to greater depths, and bedrock has been intersected much more frequently. The National Geotechnical Borehole Database, developed in the GSI, is a major dataset for the modelling of the subsurface geology in Dublin. A depth to bedrock contour map for central Dublin has been produced (GSI Annual Report 2004) and recent work has centred on a 3-D model showing the elevation (metres OD Malin) of the buried bedrock surface (Fig. 4). This modelling has been carried out using a dataset of 1,528 boreholes which met rock out of a total of 4,399 digitised borehole locations in central Dublin.

The Bedrock under Central Dublin

In central Dublin the bedrock is totally obscured by the overlying glacial and postglacial deposits. The bedrock is "Calp" limestone (Lucan Formation) and is estimated to be up to 800m thick (Nolan, 1985). The homogeneous sequence consists of dark grey massive limestones, shaley limestones, and massive mudstones and cherts are common. The average bed thickness is less than 1 metre, but these normally thin-bedded lithologies can reach thicknesses of 2m or more. Conjectural minor synclinal and anticlinal folds cross the city with a NE/SW orientation. There is also some cross faulting in a N/NNE direction. No large-scale cavitation has been observed in the "Calp" limestone.

Typical Lucan Formation (Calp Limestone). Liffey Valley shopping centre slip road, off N4. Photograph by Andy Sleeman (GSI) 2005

The Superficial Deposits

Glacial till (Boulder Clay) has a widespread distribution across central Dublin. It has traditionally been divided into two strata, an upper Brown Boulder Clay and a lower Black Boulder Clay for engineering purposes, the upper unit being a weathered facies of the lower. These sediments can vary greatly in thickness, from a few metres to upwards of 20m. The till contains water-bearing lenses of sand and gravel. Glacial and postglacial terrace gravels are found along the River Liffey, overlain by recent alluvium. There is a considerable area of intake from the sea in the east of the city where seawater intrudes into be glacial materials. The Liffey channel downstream of Butt Bridge contains a thick sequence (up to 40m thick) of postglacial intertidal and estuarine deposits overlying a basal glacial till (Naylor, 1965).

Till from the Dublin Port Tunnel excavation in Whitehall Dublin. Brown till is readily visible overlying the black till. (Photo, Eric Farrell, TCD)

The Bedrock Topography and the Pre-Glacial Liffey Channel

The bedrock topography is dominated by a major buried channel, the route of the pre-glacial Liffey downstream of Islandbridge. Figure 4 shows a 3-D model of the rockhead surface and the channel. This buried channel was identified by Farrington (1929). Away from this channel the bedrock lies at shallow depths of 5-10m below ground level (BGL) on average across the central city. The buried channel turns south of the present River Liffey course just to the west of Heuston Station at Islandbridge and then turns northwards under the Guinness brewery at depths of 20-25m BGL (ca. –20m OD) and on towards Broadstone. It then veers northeast towards the north Circular Road area and the East Wall and lies at depths of 25-30m. BGL (-25m OD). It has a width of ca. 1.5km here. More boreholes to bedrock are needed in this section to more accurately define the channel geometry. It then turns southeast towards the sea, running diagonally across the Alexandra Basin and the Ringsend Peninsula. The channel walls and floor are well defined here by the many boreholes which have been drilled for port development works (Naylor, 1965). The bedrock lies at –40m OD or below under the Ringsend Peninsula. It is approximately 2.5km wide at this location. The boreholes indicate that there is a second channel sub-parallel to the main channel in the area of the Bull Wall, possibly due to parallel lines of weakness in the bedrock here (Naylor, 1965). It is believed the buried channel extends on out into Dublin Bay in a southeasterly direction. As yet there are insufficient boreholes to model the channel much beyond the South Bull Wall.

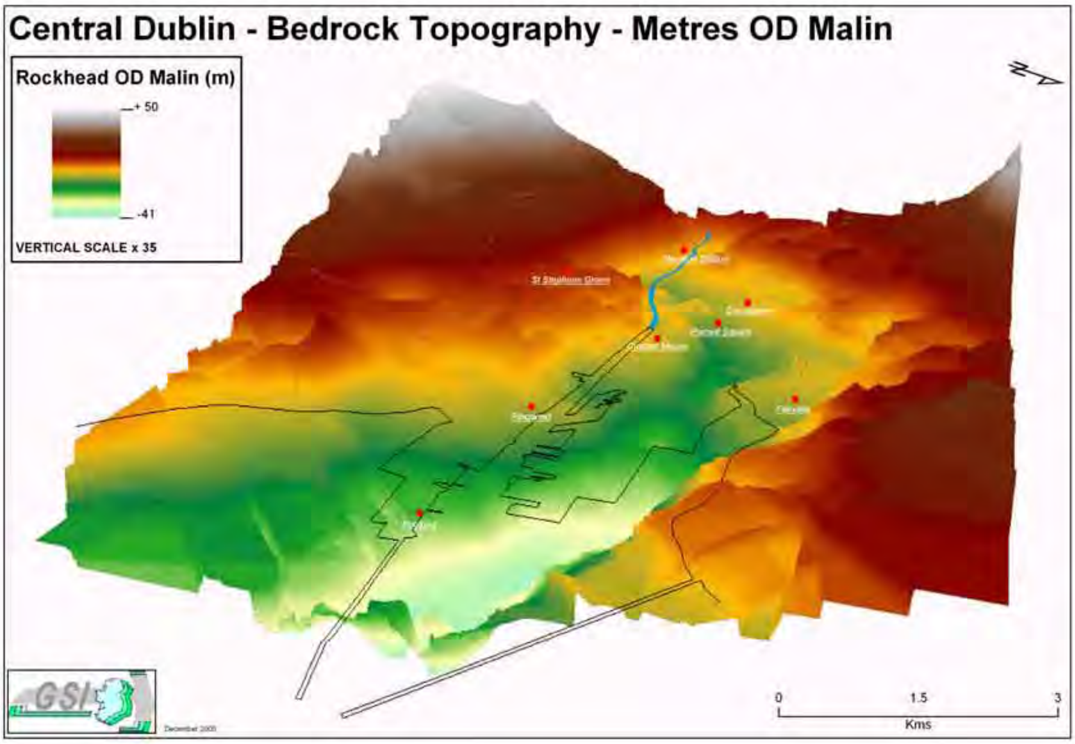


Figure 4. 3D model of the bedrock surface under Dublin City

By contrast the modern River Liffey flows straight past Heuston Station eastwards towards the sea crossing the buried channel between the station and the Four Courts. The next section as far as City Quay crosses an area of shallow rock where the bedrock is at 5-10m BGL. It then crosses the plunging south bank of the buried channel where the bedrock descends from –10m to – 20m OD in the area of the East Link Bridge. As the river widens eastwards in the port area it crosses the deepest part of the buried channel (- 40m OD) in the area of the South Port.

The abandonment of the buried channel by the modern River Liffey for much of its passage through the city centre is due to processes of erosion and deposition related to changes of sea level in the lateglacial and postglacial periods. As the ice retreated the original channel was re-excavated to almost its original depth (-40m OD) at a time of low sea level and glacially derived clays and gravels deposited. Then began a long period of marine transgression into the bay. Overlying the till and glacial gravels is a firm to stiff laminated clay with shells deposited in an intertidal or estuarine environment. It has an average thickness of 3-5m but thickens to over 20m in the vicinity of the power station. Then foreshore deposits of gravel and sand followed by offshore marine clays and sands (Naylor, 1965) were deposited. At the top of the sequence are the recent mud deposits of the River Liffey. The preglacial channel was effectively filled up with these sediments.

This summary of the subsurface geology of central Dublin illustrates the complexity of the superficial deposits, in terms of both their type and thickness, and the variable depth to bedrock found across the city. The delineation of the buried channel including its depth, width, and sediment fill is crucial in the context of underground infrastructure planning and design. The 3-D model shown in Figure 4 is a first approximation of the bedrock surface in Dublin city centre. It will be further refined and improved upon as more boreholes are added to the database.

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FOLLOWING THE FOOTSTEPS OF DINOSAURS

Joanna Wright (University of Colorado at Denver)

Dinosaurs have fascinated people for many years, probably due to a combination of their huge size, the fact that they lived so long ago and the way they were so different from modern life forms by, for example, walking on two legs, or having so many plates, spikes and horns. But because they lived so long ago, all that remains is their bones, no flesh remains to give us any idea about what they looked like in life. We have to put their bones together and make inferences about what they looked like and how they moved. But we do have another weapon in our reconstruction armoury – the fossilised footprints of dinosaurs. Fossil footprints, or tracks, are the nearest we may ever come to observing a live dinosaur! Tracks are a record of the life activity of dinosaurs; by studying tracks we can find out how they moved and where they wandered.

Dinosaurs lived during the Mesozoic Period, between about 235 and 65 million years ago. Not all fossil animals were dinosaurs and not all large reptiles that lived during the Mesozoic were dinosaurs. Pterosaurs were flying contemporaries of dinosaurs, and there were also various marine contemporaries of dinosaurs including plesiosaurs, ichthyosaurs and mosasaurs. Birds are actually living dinosaurs, having evolved from small meat-eating dinosaurs sometime during the Jurassic Period. No dinosaurs have been found in Ireland because the country was underwater during the Mesozoic but a few marine reptile fossils have been reported.

Despite the fact that the study of fossil trackways is regarded as a bit of a sideline, in actuality not only was the utility of tracks recognized early on, but the first remains of dinosaurs to be scientifically described were fossil tracks. The Reverend Edward Hitchcock, Professor of Geology and Theology at Amherst College in Massachusetts (Figure 5), described the fossilized tracks of what he

Figure 5. The Reverend Edward Hitchcock and some of the fossil tracks displayed in the purpose-built museum "The Appleton Cabinet" at Amherst College, Mass., USA.

thought were giant birds and marsupials in 1836, six years before the word dinosaur was formally coined. Dinosaur tracks gave us the first clue that some dinosaurs walked bipedally. For instance, in the eighteen-fifties, Samuel Husband Beckles described some large three-toed tracks from the foreshore at Hastings and noted their remarkable similarity to the feet of *Iguanodon*, a large plant-eating dinosaur known then only from fragmentary remains in England but thirty years later to be found in large numbers in Belgium where their bipedal locomotory style would then be formally recognized. *Iguanodon* would soon star in the Arthur Conan Doyle novel – *The Lost World*; Doyle lived in the south of England and the large three-toed tracks were well known to him. One even featured on the cover of one edition of the book (Sarjeant 1989), although unfortunately it was the footprint of a large theropod (meat-eating dinosaur).

Tracks can be used to determine the speeds of their makers by observing that the relationship between stride length and speed in modern animals is remarkably consistent across many groups of animals as diverse as horses, ostriches, hedgehogs and humans, and so it is likely that it would also hold true for dinosaurs (Alexander, 1976, 1989). We can estimate the size of the dinosaur that made the tracks from the length of the footprint, and determine what type of dinosaur it was by comparing the footprint morphology with known foot skeletons of dinosaurs (Figure 6).

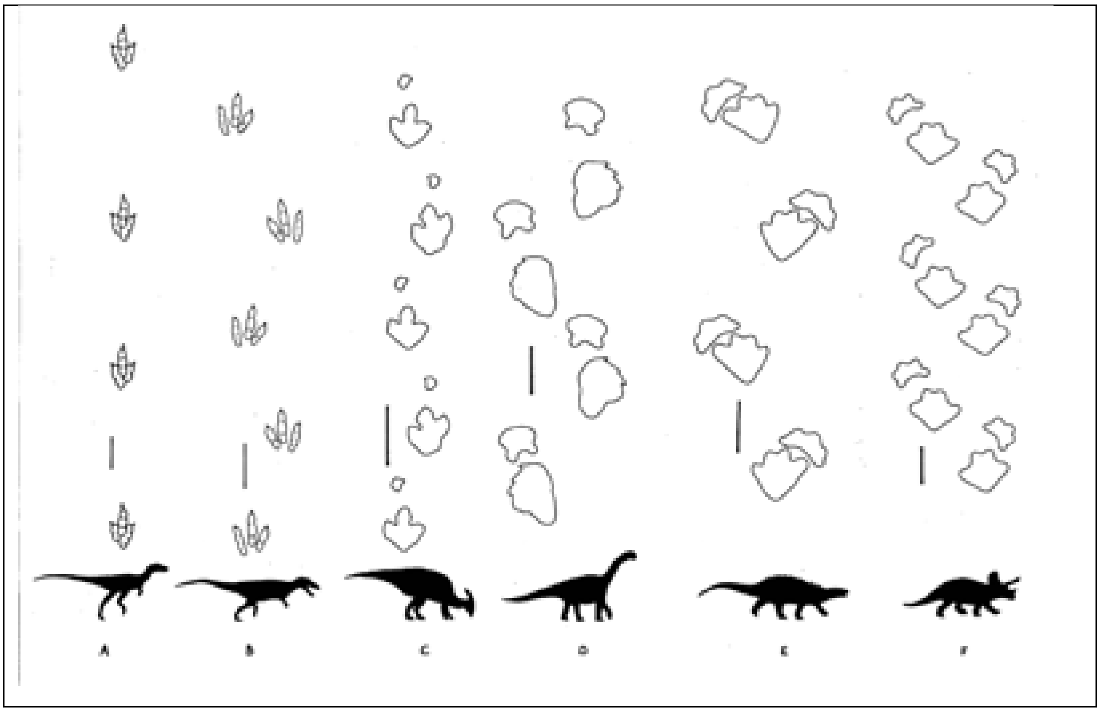

Figure 6. Some common dinosaur trackways and their producers. A. Grallator trackway probably made by a small theropod such as Coelophysis. Large theropod trackway probably made by an allosaurid or megalosaurid. C. Caririchnium, large quadrupedal ornithopod trackway probably made by an iguanodontids or hadrosaurid. D. Brontopodus trackway made by a sauropod. E. Large quadrupedal trackway probably made by a nodosaurid ankylosaur. F. Ceratopsipes trackway probably made by a horned dinosaur. Scale bar in A 10cm, B-F 50cm (from Wright & Breithaupt 2002)

One of the problems with the study of vertebrate tracks has been their classification. Various attempts have been made to use multivariate statistics on landmark points but this has yet been fully successful. This is probably because tracks do not have as many morphological features as body fossils. The problem of a limited number of landmarks could be bypassed if the entire outline of tracks could be compared quantitatively. However, as tracks are biogenic sedimentary structures – a product of the interaction of an animal's foot with the substrate - the boundary of a track is not as clear cut as with body fossils, and different researchers might choose different outlines.

Tracks can also be difficult to photograph; lighting from different directions can show different morphological features and make a track look very different (Figure 7A-C). At CU Denver we have been working on ways to image fossil footprints so that the outline of a track is defined by the maximum slope of the impression (Figure 7D) which will help to reduce subjectivity in describing and comparing tracks. This has important implications not only for track classification but also for comparison of track features due to locomotion or substrate conditions.

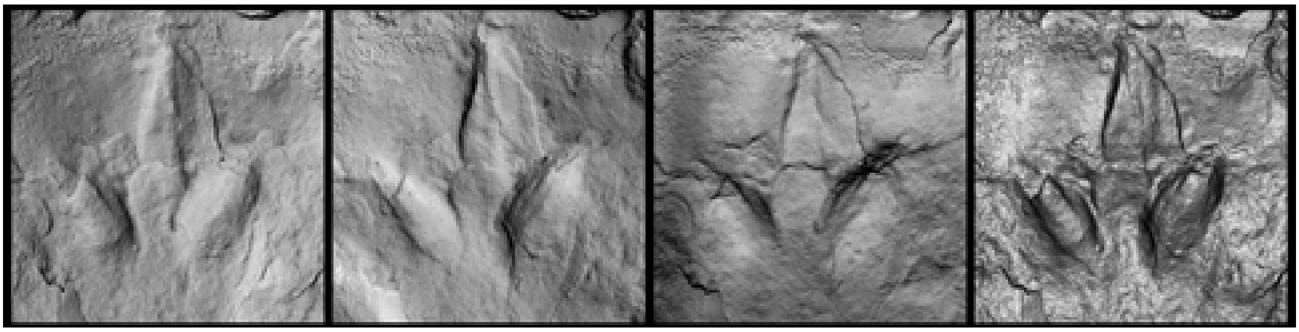

Figure 7. A track with lighting from three different directions and a composite image of the same track combining information from the different lighting directions to produce a relief map of the track – the darker the colour the steeper the slope (photos and imaging program courtesy of Greg Lobser, Department of Mathematics, University of Colorado – Denver)

Tracks have traditionally been used to determine walking and running speeds in dinosaurs and to confirm their presence in certain places or at certain times but recently there has been some innovative research into dinosaur tracks as trace fossils rather than just as a proxy for body fossils. That is the way tracks are preserved as a dynamic interaction between the animals foot and the sediment can be used to find out more information about how the animal moved and what the substrate conditions were at the time of track formation (Gatesey et al., 1999). Both experimental studies and sophisticated computer animation programs are important tools in this line of research. Thus tracks have the potential to reveal to us a great deal more information not only about the presence and locomotion of dinosaurs or other trackmakers but also about palaeoenvironmental conditions at the time of track formation.

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THE BRAY EARTHQUAKE

Brian McConnell

An earthquake measuring 2.8 on the Richter scale occurred in the Irish Sea off Bray Head at 3.30a.m. on 14th December 2005. The epicentre (Lat: 53.0° North, Long 5.64° West; Grid Reference 155.7km E, 351.1km N) was in an area not too far from a magnitude 3.7 magnitude event recorded in 1951.

The largest recorded earthquake in the Irish Sea area measured 5.4 on the Richter scale and had its epicentre on the Lleyn Peninsula in Wales on 19th July 1984 (see map). Many geologists on the east coast of Ireland remember the day! Although relatively large, the focus of the earthquake was quite deep, about 20km, and so structural damage was minor, and it was only weakly felt in Ireland. Two other recent earthquakes have occurred in the same area, in 1994 (magnitude 2.9) and 1999 (magnitude 3.2).

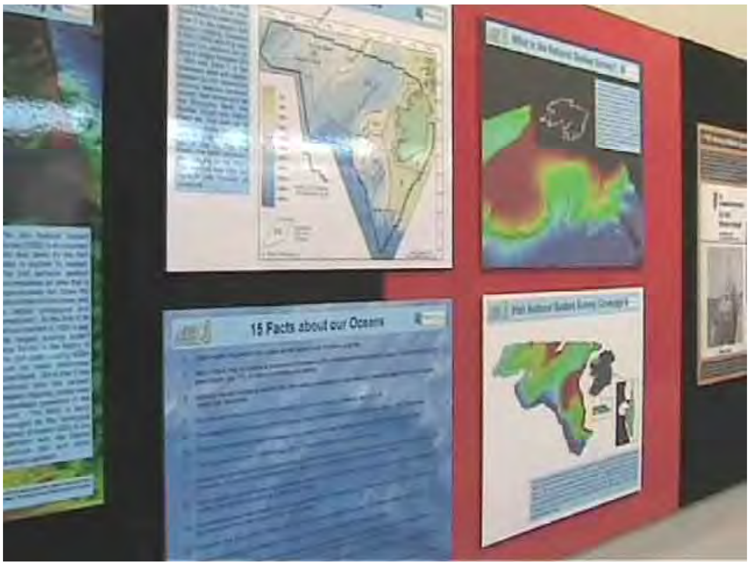
This cluster is located along the Menai Straits fault zone, a major fault structure that runs across the Irish Sea to pass south of Carnsore Point. The fault dates back to the assembly of Ireland and Britain during the Caledonian orogeny (at least 400 million years old and perhaps as old as 520 million years) and it is probably a terrane boundary, that is, a fault zone separating two different blocks of the Earth's crust. Such major faults remain seismically active over geological time.

The earthquake prompted Mr. Gay Mitchell T.D. to ask a Parliamentary Question in the Dáil on Ireland's preparedness for a serious earthquake or resulting tsunami. The reply indicated that "The Geological Survey of Ireland is currently co-ordinating a national initiative to develop a proposal for an early warning system within international frameworks." The Dáil question and reply provoked a minor flurry of interest in the media, some reporting that UNESCO has recently decided to establish a tsunami early warning system in the northeast Atlantic and, in developing its system, Ireland would seek to be part of this. Look out for more about this in future editions of 'Geology Matters'.

SEABED SURVEY EXHIBITION MOVES TO ENFO – FEBRUARY 6

Enda Gallagher

GSI's colourful exhibition detailing the survey of Ireland's extensive seabed will take up residence in the exhibition offices of ENFO* this February. The four-week residence commences on February 6th. Later in the year it will have a similar run in the EPA offices in Johnstown Castle, Co. Wexford. With stunning imagery and limited text the exhibition takes the visitor on a whistle stop tour of the world's largest seabed mapping programme. It very simply explains what the survey is about, why it is important and also illustrates how the survey is undertaken – the ships being used, the types of people involved and the equipment that is essential to the survey.



A separate theme of the exhibition is the celebration of our oceans. Panels vividly highlight dolphins and seabirds, our shipwreck heritage, our extraordinarily colourful coral reef assets and some interesting facts about oceans. In addition, two panels succinctly outline the history of marine surveying in Ireland, from yesteryear when the leaning over from small boats and dropping weights to the seafloor was the commonplace means of determining the depth to the seabed, to the high-brow laser and acoustic technologies of today. We explore the data being acquired, their uses and some of the products resulting from them. We document the international appraisal of the Irish survey and the important spin-offs for the Irish marine sector.

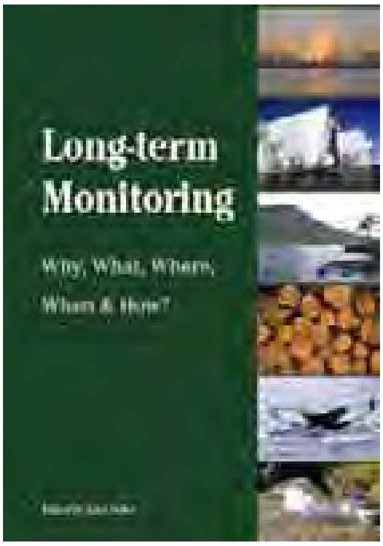
GSI believes that exhibitions represent an effective way of raising awareness about geology and geological heritage. We have a permanent exhibition area which houses various exhibits on a temporary basis before they are loaned out to libraries, Local Authority offices and local museums. Glass display cases facilitate the display of interesting visuals including rock samples and equipment. For further information about our exhibition programme please contact Enda Gallagher at enda.gallagher@gsi.ie or 01 678 2000.

* ENFO is Ireland's public information service on environmental matters and it is located at 17 Andrew Street, Dublin 2.

SHERKIN ISLAND MARINE STATION
Long term monitoring: Conference proceedings

Yet another fine publication emerges from the production line of the Sherkin Island Marine Station, Co. Cork. This time it's a book of the proceedings of a workshop and conference *"The Importance of the Long-term Monitoring of the Environment"* which was hosted by the Marine Station from 14th–19th September 2003 on Sherkin Island itself.

Edited by Professor John Solbé, an environmental consultant based in Wales, the book runs to more than 200 pages with about 30 pages reporting on the discussions of the workshop and the remainder detailing the conference papers. In his introduction to the book Dr. Barrie Dale provides a background to the conference pointing out that uncertainty is a major factor in public concern over environmental degradation. In an ideal world he points out that we would tackle environmental problems by first being able to fully understand the problem based on adequate data, particularly long term observations. These are not readily available owing to a lack of foresight and resources in times past. He says that for these reasons, "we are forced into making estimates of environmental change in the absence of adequate background information. In practice this involves using available, mostly short-term, observations to answer questions requiring longer-term series of data, with a heavy reliance on modelling to help make up for the shortfall". The workshop and conference explored this subject of a dearth of long-term monitoring data and illustrated the importance of maintaining the few long-term series of observations we have in place throughout the world and starting new series as required.



Topics covered in the workshop included the definition of long term monitoring, types of data required, quality control issues and the communication of results to the wider public. Papers prepared for the conference included one by our own Director Dr. Peadar McArdle, on "The role of Geology in long term monitoring". Other papers dealt with topics ranging from the social value of long-term monitoring, to the Sherkin Island Marine Station's own long-term monitoring programmes and the role of the EPA in environmental monitoring in an Irish context. The soft-back book is available for purchase from Sherkin Island Marine Station, Sherkin Island, Co. Cork, Ireland, Tel: 028 20187, sherkinmarine@eircom.net, www.sherkinmarine.ie at a cost of €44.50 including postage.

INFOMAR – Mapping Ireland's near shore

Eibhlín Doyle

1999 was an historic year for Ireland's offshore territory as it was in that year that the Irish Government recognised the need for a comprehensive seabed survey to map and identify the opportunities for Ireland's extensive seabed territory and approved the **I**rish **N**ational **S**eabed **S**urvey (INSS). The late Dr. Ray Keary of the Geological Survey of Ireland (GSI) championed this magnificent project. The INSS finished in 2005 but the energy and momentum created by the INSS has generated a successor project to be known as INFOMAR (**IN**tegrated mapping **FO**r the sustainable development of Ireland's **MA**rine **R**esource). INFOMAR builds on significant expertise developed at the GSI and the Marine Institute (MI) during the INSS.

The achievements of the INSS are significant and far-reaching. To date 87% of Irelands offshore area has been mapped using, all waters greater than 200m water depth have now been mapped using multibeam, shallow seismic, gravity and magnetics (Figure 8). Limited groundtruthing has been undertaken to assist with interpretation of the nature of the seabed. The data has been and continues to be the focus of a large number of research projects. In addition the data has contributed significantly to safety at sea, conservation of vulnerable habitats and supporting various marine industries (fishing, energy, aggregate etc). INSS has been an inspiration to other maritime nations for the collection of integrated marine data.

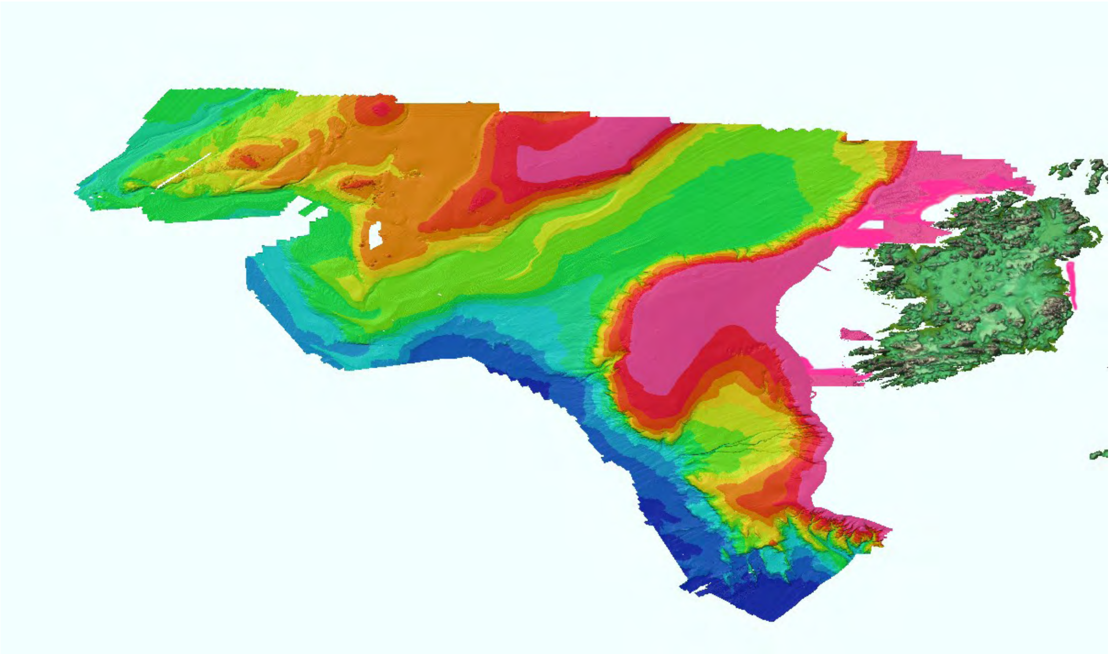


Figure 8.

Following a joint submission to government by GSI and MI, a government decision established the successor programme to the INSS. This programme will continue to map Ireland's offshore territory but with an emphasis initially on near shore concentrating on prioritized bays and designated areas (Figure 9). A total of 26 priority bays and 3 priority areas have been identified.

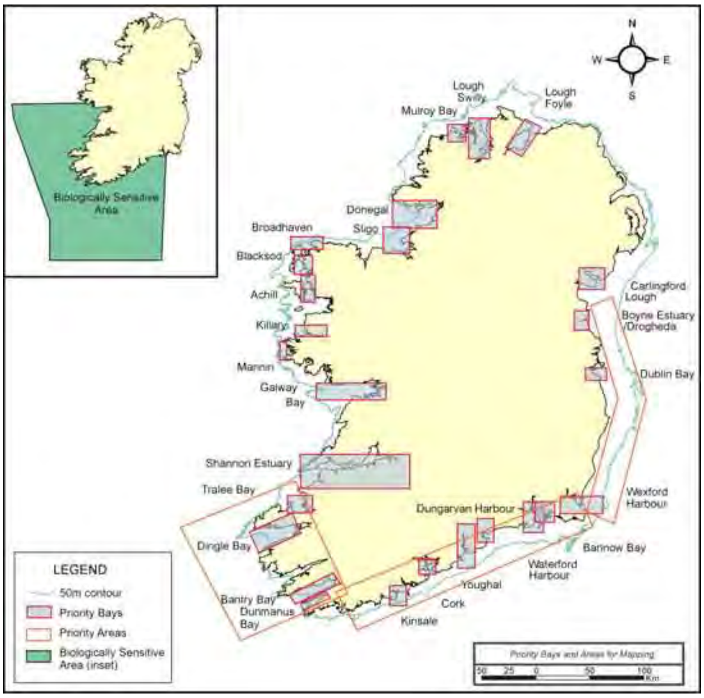


Figure 9. Prioritised bays and designated areas of INFOMAR.

The beneficiaries of modern bathymetric data are as many as those who use the sea and include shipping, fishing, aquaculture, seaweed harvesting, natural resources, engineering, infrastructure, renewable ocean energy, marine archaeology, and leisure sectors as well as providing stimulus and data to those involved in marine research. Detailed mapping will help reduce conflicts in the coastal zone by providing information on the different potential resources and options available. This will allow a more enlightened approach to be taken to the designation of areas for different activities and the highlighting of areas in need of special protection. It will supply policy and decision makers the necessary tools to provide for responsible sustainable management of our offshore resources and will assist the development and growth of many of the sectors listed above.

The many products and services that will flow from the data collected will continue to support the growth of the marine sector. Modern bathymetric data is essential not only to fully realise the full potential of our offshore resources but most importantly for safety at sea.

The INFOMAR team look forward to keeping you informed on our progress during 2006 and into the future.

25TH ESRI WORLD GIS USER CONFERENCE

Eddie McMonagle, Cartography Unit

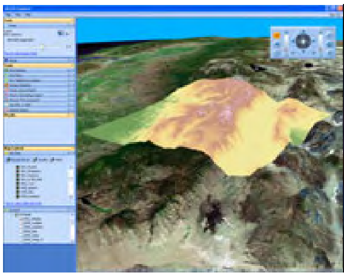
The world's largest Geographical Information System user conference took place in July 2005 in San Diego. ESRI's first GIS conference took place in 1981 attended by 16 GIS 'cracks' that shared their experience and infancy vision of Geographical Information. The 2005 event was ESRI's 25th celebration attended by 13,000 new 'heads' with diverse backgrounds from 130 countries worldwide.

The 2005 topics and seminars provided valuable GIS software updates, 300 technical sessions, vendor exhibits, user meetings, training classes, group activities and one-on-one consultations with software experts. More than 150 special interest user group meetings, dozens of regional user group meetings, and more than 2,000 user paper presentations.

The conference provided a good look at the vision and direction for desktop GIS with upcoming release of ArcGIS 9.2 (due in Mid 2006). Users can expect changes and enhancements that target *quality*, *usability*, and *performance*. Key areas focused on modelling, visualization, cartography, spatial analysis, the geodatabase, more productive mapping and visualisation tools and the complete migration of all ArcInfo tool functions to ArcGIS – a longstanding user request. We were informed that the role of GSI within organizations is changing. More of the work that "doesn't need the power" is being pushed out to ArcIMS (Web GIS) applications and ArcGIS Server.

These new developments will support 2D and 3D globe visualization and data analysis of geo-data at a global scale. ArcGlobe has been called ESRI's "Google Earth killer" among other things. ArcGlobe when you remove its skin is a sphere with x,y coordinates represented bylLatitude and longitude and its z elevation represented by above mean sea level. Any input data is then projected to WGS84 world projection. While ArcGlobe has some similarity with the free Google download, it also connects to ESRI powered 3D data via ArcGIS Server and ArcIMS Services.

Recent GIS development in GSI
ArcExplorer (current version) has been successfully tested and incorporated in the creation of GSI 1:100,000 series as a new GIS interactive CD product. It was also incorporated into the prototype for a new 1:50,000 scale bedrock map series by Ray Scanlon in Bedrock section. It is envisaged that additional products will be developed using ArcReader to view and interact with published digital maps. Future product developments for GSI customer clients will see an increase in provision of GIS 'services'. Such developments might see less of an emphasis towards hardcopy map output, replaced by dynamic, interactive (GIS functionality) mapping and GSI datasets via web mapping services such as ArcIMS and client ArcExplorer. There is an increasing priority to allocate more time to organize and advance new GIS data uploads and to focus on development within GSI's ArcIMS. Future datasets will also see increased provision and utilization of 3D to complement existing 2D geological datasets.



THE CUNNINGHAM AWARDS, GSI, 2005

On Friday 9th December, GSI celebrated the presentation of the 21st Mark Cunningham Awards. The Awards are presented by the Cunningham family in memory of Mark Cunningham (1908 – 1980), late Assistant Director of GSI. The awards include two College Prizes and two Survey Prizes and are presented each December at an informal ceremony and Christmas lunch hosted by the GSI in its office in Beggars Bush. Representatives of the Cunningham family attend along with current and recent staff members and invited guests from within and outside the Department.

College Prizes are awarded to the two best geological mapping project reports submitted from undergraduates at third level colleges each year. Over the years various colleges have been successful in the competition but this year it was two Dublin colleges that took the honours. Eleanor Donoghue from the Department of Geology, Trinity College took one of the prizes for her thesis entitled *"The Geology of Glen Dibidil, Isle of Rum, Scotland"* whilst the other was won by Eoin MacCraith of the Department of Geology, University College, Dublin with his thesis *"The Solid Geology of the Dunquin area, Co. Kerry, Ireland"*. The winning theses were on display in the Survey's Customer Centre on the day of the Awards ceremony, attracting much interest from the assembled guests. In presenting the prizes the Director of GSI, Dr. Peadar McArdle complimented the winners describing their work as being of "an exceptionally high standard."

There are two Survey Prizes for members of GSI staff for an outstanding contribution to the work and development of the Survey. For 2005, these were awarded to Margaret Nolan, Central Administration, for her "consistent high level of productivity throughout the year," and to John Dooley, Cartographic Unit, for his "adaptation to new technologies with enthusiasm and his dedicated service to GSI over many years".

Awards were also presented at this ceremony to winners of the DuNoyer Photographic Competition which is sponsored by the Irish Geological Association and the GSI. 2005 was the seventh year of this competition for photos of geological interest. The Competition is named after George Victor DuNoyer (1817 - 1869), a skilled artist who worked for many years with a youthful GSI who illustrated his observation on the geological maps on which he worked. As is customary, all photos entered for the competition were on display.

ES2K begins association with SCIENCE SPIN Journal

ES2K, the all-island magazine published by Earth Science 2000 and with the stated aim of "raising awareness of Earth Science across Ireland," is to be incorporated into SCIENCE SPIN magazine. SCIENCE SPIN is Ireland's Science, Wildlife and Discovery magazine. ES2K will take a clearly defined section within each bi-monthly issue of the magazine. The increased frequency of publication will enable ES2K to report on issues in a much more timely manner than before. Also, tying in with SCIENCE SPIN in this manner has the added benefit of attracting a substantially increased readership. This has been made possible through the financial support of GSI, which regards the transition as an important element of geological outreach.

ES2K editor, Dr. Tony Bazley, believes the move to be a very positive one, saying that "it will enable us to exert more influence in the development of earth science in Ireland." He says that the style of ES2K will not change and that forthcoming SCIENCE SPIN issues will encompass around eight pages of ES2K material. As always, contributions from around the country, either to Tony directly or to the various regional correspondents, are gratefully received.

ROCK BITS
Getting Blood from a Stone

From where did this common phrase originate and what does it mean? The proverb is found in varying forms:

- You can't get blood out of a stone;
- You can't get blood from a rock; or
- You can't squeeze blood from a stone.

The stone here is a metaphor for a person who simply does not have (or would never give up) what is being sought - usually money. Often the tax man is implicated. The proverb has been traced back to G. Torriano's 'Common Place of Italian Proverbs' (1666). In Naples and Pouzzoli there is the Saint Genaro who was killed by soldiers. On his feast day every year, the rock where he was beheaded is said to bleed and this is taken as a sign that the area will be protected from volcanic activity for the upcoming year. Very apt from a geological point of view.

The phrase was first used in the United States in 'Letters from William Cobbett to Edward Thornton' (1800). Charles Dickens also used the saying 'Blood cannot be obtained from a stone', in 'David Copperfield' (1850) and then recorded the exact wording in the modern version in 'Our Mutual Friend' (1865).

Jennifer Armstrong penned the following poem around a word ladder. A word ladder is where one letter is changed from the proceeding word to make a new sensible and correct (English) word. In this example initial word ***stone*** has been transformed step by step into the final word ***blood*** as follows *stone, store, stork, stark, stack, slack, clack, clock, cloak, croak, crook, brook, brood, blood.* And as the poem has 14 lines it is a sonnet of sorts.

For a metaphor of art, also here called blood, begin with stone:
sedimentary, igneous or metamorphic, a store
of mineral trash and grit such as a stork
might collect, standing lock-kneed on the stark
shoreline, arranging, forming a stack
of pebbles one upon another until it tumbles, falls slack;
it won't give up, but tries again. The mandibles of its long beak clack
as it roots and dibbles in the mud for the right piece, ignoring the clock
of the sun that ticks toward the evening and draws the cloak
of damp dark over the day. The bird sounds a dry croak.
Why does it persist, why does it ignore the baby birds there in the crook
of a log back in the tall grass, back where the brook
noses its way through reeds to find the bigger water. The brood
waits, ogle-eyed, watching the artist on the shore try again to draw blood.

So, you see you can get blood from a stone after all.

Information relating to 'Getting Blood from a Stone' has been obtained from the following material:
"Wise Words and Wives' Tales: The Origins, Meanings and Time-Honored Wisdom of Proverbs and Folk Sayings Olde and New" by Stuart Flexner and Doris Flexner (Avon Books, New York, 1993).
"Random House Dictionary of Popular Proverbs and Sayings" by Gregory Y. Titelman (Random House, New York, 1996).