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Geoscience after IT: Part D

Familiarization with IT applications to support the workgroup

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Abstract - Once geoscientists have acquired basic computing skills, the next step in IT familiarization is generally to use IT methods to collaborate within a project. The project is managed to achieve the objectives of a workgroup. Computers facilitate communication with e-mail, discussion groups and intranet links. There may be a need to formalize: standards, metadata and investigational design for all contributors to share compatible results; procedures to monitor and control the project; and document and database design to deliver a uniform product.

Key Words - Project support, workgroup communications, workgroup documents, metadata, standards.

1. Project and workgroup

Few of us, even as students, work alone. After acquiring basic computing skills, the next step is to look at the techniques for supporting a project and enabling a workgroup to collaborate more effectively. Communication and preliminary planning are obviously important, as are databases and quantitative models. This leads on to the wider scene, where we recognize the global scope of geoscience and the pervasive influence of information technology.

We began (part C, section 2) by looking at the desktop computer. Without external distractions, you can develop basic skills there, such as using a keyboard, a graphical user interface and basic tools for preparing text, diagrams and data files. Most geoscientists, however, must inevitably relate their own specialist expertise to the knowledge of others within a **workgroup** - a number of individuals brought together to work on a defined task. This creates additional requirements for information technology to assist in communication and coordination.

Tasks are normally handled as projects. A **project** is a managed activity with a set of objectives and a time scale, normally with identified requirements for resources of staff-time, equipment, services and information. The objective may be as small as the identification of a fossil, or as large as the production of a geological map of the world. A large project can be divided into subprojects. A very large project, say the geological surveying of the United States, might be regarded as a service activity with no final completion date. It would subsume many projects, concerned perhaps with completion of specific reports or map sheets.

A project is defined within a business context rather than a purely scientific one. Consequently, the geoscience aspects would be designed and conducted differently for, say, a project estimating sand and gravel resources compared with one looking for oil and gas. **Business** is defined rather broadly as activities to meet the objectives of the organization. A graduate research study, say, would reflect the "business" of the university in terms of research and education. Knowledge of the business context in which the project is undertaken is essential for others to evaluate the results obtained and their significance in other contexts. For example, core samples from oil exploration might not be representative of the area because they were selected as potential hydrocarbon-bearing rocks, possibly obtained from anticlines selected by seismic survey.

2. Communicating in the workgroup

Communication between participants in a project can be improved by IT, and the closer coordination can make work more productive. Where it is impossible or undesirable for all participants to be accommodated at the same location, IT can offer good communication links over long distances (E 4). Tasks within a project can be divided among a range of experts, all with their own computing needs and solutions. They must combine their results and share their resources. Information must be transferred between machines and must be usable when it arrives. The benefits of working together, as well as the ability to make the results of the project available to others, therefore depends on compatibility and consistency within the project and comprehensibility to the outside world (H 2).

IT offers a variety of communication methods, from the familiar telephone and fax to e-mail, file transfer, teleconferencing, distributed computing and project management (D 5). Communication can be between two individuals, one individual addressing a group, or discussion within a group (one-to-one, one-to-many or many-to-many). The message can be actively directed at specific recipients (push), or can be made available, appropriately labeled, to be collected by anyone interested (pull). The exchange of information can be ephemeral or intended to provide a lasting record. It may consist of speech, written text, images, data files or computer programs, and be required for reading as a paper document, for display on a computer screen, for storage on the computer or on hard copy, or for computer analysis and manipulation. There may be a need for interaction, possibly requiring instant response, or possibly a considered response at a later date. It may be necessary or desirable to limit access to the information. Most of these needs are quite general, but the solutions depend on the available technology.

The attributes of conventional methods of communication are familiar. Standards and protocols are adopted, such as the behavior expected at an interview, the formality and sequence of a letter, the procedures, agenda, minutes and control of a meeting to ensure orderly discussion. Similar requirements arise in electronic communication, but may be resolved differently.

Electronic mail (E 4) communicates by means of messages entered at a keyboard. It automatically transmits the sender's name and address, and a copy can be stored on the sender's or recipient's own file, or on both. The recipient can read the message on the screen, print it, forward it to others with or without added comments, and can reply without reentering the sender's address. Each message can be sent to an individual, members of a group, addresses selected from a database, or a complete mailing list. Mailing lists can be typed in, acquired from other sources or built up from user requests. Computer-readable documents, including data files and computer programs, can be sent by e-mail. Like the telephone, response can be immediate, or, like ordinary mail, can be timed to meet the convenience of the sender. The inevitable delays in handling paper documents, however, are partly overcome. Unlike fax, the information must be entered from a keyboard, which may make it more difficult to create a document, but is likely to make it easier to edit.

Although e-mail was designed primarily for sending text, options are available to attach images, voice and video in multi-media systems. Other special-purpose systems include **voicemail** for storing and forwarding spoken messages, and **teleconferencing** in which a group can hold a discussion through videophones without assembling physically at one location. **Usenet** provides discussion forums that are not limited to one place, time or discipline. They can be deliberately restricted to project members, to nominated list of participants, or can be open to all. Entries can be selected, edited and controlled by the discussion leader, or circulated as received. Authors and their affiliations can be included at any level of detail, or entries can be anonymous. Those with an interest in the subject can be asked to respond, can be invited to join the forum, or the existence of the forum can be publicized, with or without an invitation to register.

Techniques like the Usenet, newsgroups and the World Wide Web (E 4) are directed primarily at global rather than local communication. Nevertheless, their procedures and protocol can be used in a restricted setting, with the advantage of compatibility with the wider world to which they may sooner or later be linked. The successful concept of the **intranet** is based on similar reasoning, offering local connections with the same software and characteristics as the Internet. These tools may assist in the preparation of documents and databases as a shared activity, with many contributors working on them together.

3. Sharing information, metadata

The ability to understand the work of others, including the language they speak, depends on a **shared coding scheme**, that is, expressions of ideas and information which mean the same to the sender and the recipient. This implies a shared background understanding. Outsiders may not be able to appreciate fully the results from a project because necessary background information is not available to them. It must be explained at an appropriate level, explaining enough for features specific to the project to be taken into account. For example, a petroleum geologist needs background information to evaluate core descriptions prepared by others during development of an oilfield. Information stating when the wells were drilled, the way the core was obtained, when it was described, under what conditions, by whom, with what ends in view, would all help in the evaluation of the description.

These aspects, however, would not be part of the data (the description of the cores). Rather they are **metadata** - data about the data - which may be helpful in their interpretation (A 1). The fundamental feature of metadata is this ability to carry information at a higher level than the data, and so assist in their understanding. Metadata are often recorded formally, as on the title page of a book (author, title, publisher, date of publication, etc.), or on the legend of a map. Also, the header of a downhole log records date, time and place, and is likely to include other information about the type of logging tool and the characteristics of the drilling fluid, all of which help in the interpretation of the log itself. There is a hierarchy of metadata. Information from the headings of downhole logs might be assembled as data in a database, with higher-level metadata referring to the wells for which the suites of logs were obtained.

The metadata that enable scientists to understand the work of others are not always explicit. Understanding often depends on the expert who can infer from past experience the significance and reliability of diverse sources of possibly conflicting information. In some cases, this expertise depends on knowledge of the techniques, procedures, personalities and local background, much of which (if only to avoid libel suits) would never be recorded. One effect of IT is to make information more widely available and thus to separate it from local background knowledge. In these circumstances, metadata that set out the constraints and limitations of data are increasingly important.

Standards may be thought of in this context as specifications or definitions intended to be generally followed, established by agreement, custom or authority, to ensure interchangeability, quality and reliability for least cost. They may be widely adopted for methods, vocabulary, instrumentation and the like. Other things being equal, a standardized approach has great benefits. Because projects have their own unique objectives stemming from their business setting, they cannot all be conducted efficiently in the same way. Nevertheless, standards that are appropriate, available, credible and relevant should clearly be used. The metadata should state which standards were followed, for these change with time. They should describe any deviations from these standards, and procedures specific to the project. If standards are unavailable or inappropriate, datasets should be described in detail, together with details of the project in which the data were collected. Much of this will be part of the project report and not specifically identified as metadata.

Another view of metadata is taken by librarians, museum curators and archivists who are concerned with formal resource description. They tend to see metadata as offering a brief description that can be used to catalog information (H 2). Yet another view is taken by the database analyst who uses metadata to bring together information about specific topics for subsequent analysis (L 5). There are widely diverse requirements for metadata, and many solutions are adopted.

4. Designing an investigation

There is an obvious need to plan any project. In some cases, the preliminary planning may be only a broad outline that expands and develops during the investigation (J 1.6). In other cases, a project based on a well-defined model may be planned in precise detail before work starts. Some geophysical studies are like this. In the project design, it is important to be aware of relevant standards, and to use them where appropriate. Documentation should describe all datasets and aspects of the projects that could assist in their interpretation.

One task of most projects is to record the salient information, selected from the vast amount that could be observed. This process of abstraction starts with the initial observations and is directed towards explaining and throwing light on topics that bear on the objectives. As described later (J 1), the outcome may be narrative and spatial descriptions and explanations, which the scientist develops through directed observation, and may involve quantitative models, which are likely to have a statistical component.

The statistical approach is mentioned here because some of the insights and vocabulary are widely relevant and because it calls for rigorous design of the investigation. The objectives of the project define the subject of interest and hence the **population**, or the total set of observations that might in principle be obtained about the subject of interest. The procedures for making measurements and observations (**operational definitions**) should be on record, to make it easier to verify the results (see Krumbein and Graybill, 1965). The objectives, the hypotheses under consideration, and past experience determine the procedures in an investigation. The procedures for deciding when and where measurements are made can be defined as a sampling scheme.

It is obviously impossible to make all possible observations, and so we seek a representative portion (a **sample**) from which we can draw conclusions about the properties of the whole population, and about the degree of uncertainty which is inevitable in making such inferences. A rigorous sampling scheme is essential to make a valid statistical interpretation of a set of measurements (see, for example, Griffiths, 1967 or Davis, 1973). The measurements are expected to throw light on something specific (the **target population**). For example, if the purpose is to determine the overall content of uranium within a black shale unit and to map its regional variation, then the investigation should be designed with that in mind. Remembering that it is not possible to sample those parts of the shale unit that have been eroded away, and that it may not be practicable to sample those that are not exposed, the **available** (potentially accessible) population is greatly reduced. There may be some outcrops that are inaccessible in practice, reducing the available population further. Some will be easier to get at than others, and some samples can therefore be obtained at lower cost than others. A variable sampling density, if well designed, can be allowed for in subsequent analysis.

The procedures will inevitably change as the project proceeds and more is learned. The modifications should be recorded. In all projects it is helpful to ask from time to time whether the procedures of investigation introduce an unintended bias. If statistical arguments are used, do the sampling procedures give a representative, random sample? Is the sample representative of the population of interest, and the sampling density sufficient to support the conclusions? The sampling procedure should not be unnecessarily complicated, but must be devised to avoid misleading results. The procedures should be fully documented so that all participants can follow them and others can repeat the procedures to verify your results.

Another design issue that is troublesome in most projects is whether the objectives can be met with the available resources, such as time, manpower, information and equipment. This is considered next.

5. Project management

It is easier to estimate the resources required for small tasks than for a complex project. By breaking down the planned project into a series of steps, you can estimate the demands of each task separately. Records of similar completed projects may help, if you can find them. Project management software can then calculate the total resource requirements. Simple presentations such as the **Gantt chart** (Fig. 1) help to monitor progress, and ensure that participants know what must be done in what order and on what time-scale. Some systems allow individuals to maintain their own records, and combine them as a central record of progress for the project as a whole.

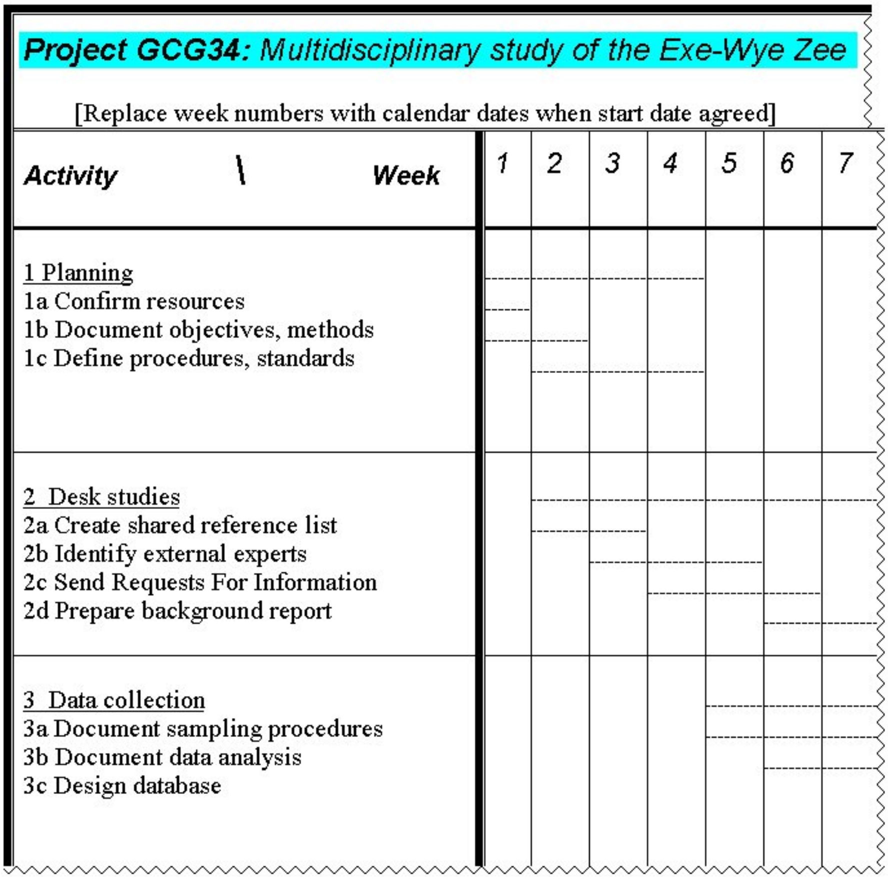


Fig. 1. Gantt chart for recording progress within a project. The work of the project is subdivided into tasks, making it easier to plan and monitor progress. Horizontal bars show the duration and time relationships of the tasks. “Milestones”, such as dates for authorization of procedures, seminars, or delivery of reports, can be shown as symbols on the bar. Individual contributions may be identified separately and linked to the contributor’s other commitments. The final documents can be extensive, and only a fragment is shown here.

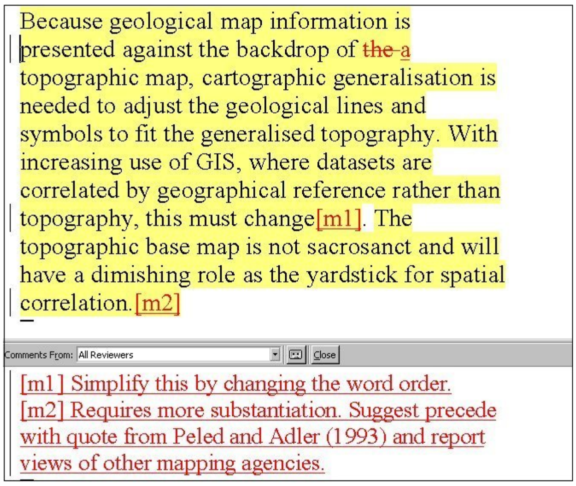
For a very large project or closely linked set of projects, **critical path analysis** (CPA) techniques may be useful. They are concerned with subdividing the project into a number of tasks and estimating the effort to complete each. Time dependencies between tasks are identified. For instance, samples must be collected before they can be analyzed. The tasks can be placed in sequence, and by comparing estimates of the effort needed with the resources available, completion dates for each task can be estimated. The critical path through the network of tasks links those that determine the shortest overall time to complete the project. To meet that completion date, the latest time for completion of any task, whether on the critical path or not, can be calculated and the consequences of any delay can be assessed.

Despite project size increasing (thanks to IT support) few geoscience projects are so complex and time-sensitive that they warrant critical path analysis. However, the technique is of interest to geoscientists for another reason. It is a means of recording events of many distinct kinds that occur in succession within the same time frame. The time taken by a process leading from one event to another may be quantifiable, or in some cases may be unknown. Before and after relationships can be incorporated where they are known, whether or not they refer to the same kind of event. The software for critical path analysis can thus be applied to geological activities, processes and events as well as human ones. It can be applied to stratigraphic relationships, linking events such as the start and end of deposition of formations, tectonic events, fossil ranges, and the like. The mathematical framework is called **graph theory** and is concerned with networks, their properties and their visualization.

Management of a project can be assisted by IT. It provides an effective means for members of the workgroup to keep in touch. Assuming that they are connected by a network, such as an intranet, bulletins can be posted centrally, or can be distributed by e-mail, to give all concerned immediate access to developments within the project. Software is available for maintaining individual **diaries** and records of time spent on various aspects of the project. All participants can update their section of a shared **movement sheet** so that they can be contacted while out of the office, and meetings can be arranged at a time suitable for all. The computer system is being used as a device to improve social interaction. But, while the project as a whole may gain, individuals may lose some freedom of movement. There is therefore a risk of subversion by unwilling participants. An enforcer, such as the project leader's secretary, may be needed to ensure timely and accurate input.

6. Project documents

When a workgroup, rather than an individual, prepares project documents, word processing enables each of several authors to contribute sections, and the principal author to fit them together and edit as necessary. The editing process is made easier by facilities such as **red-lining**, which enables the editor to **mark up** the document, to indicate suggested changes and add annotations without obscuring the original wording (Fig. 2).


Because geological map information is presented against the backdrop of ~~the~~ a topographic map, cartographic generalisation is needed to adjust the geological lines and symbols to fit the generalised topography. With increasing use of GIS, where datasets are correlated by geographical reference rather than topography, this must change[m1]. The topographic base map is not sacrosanct and will have a dimishing role as the yardstick for spatial correlation.[m2]

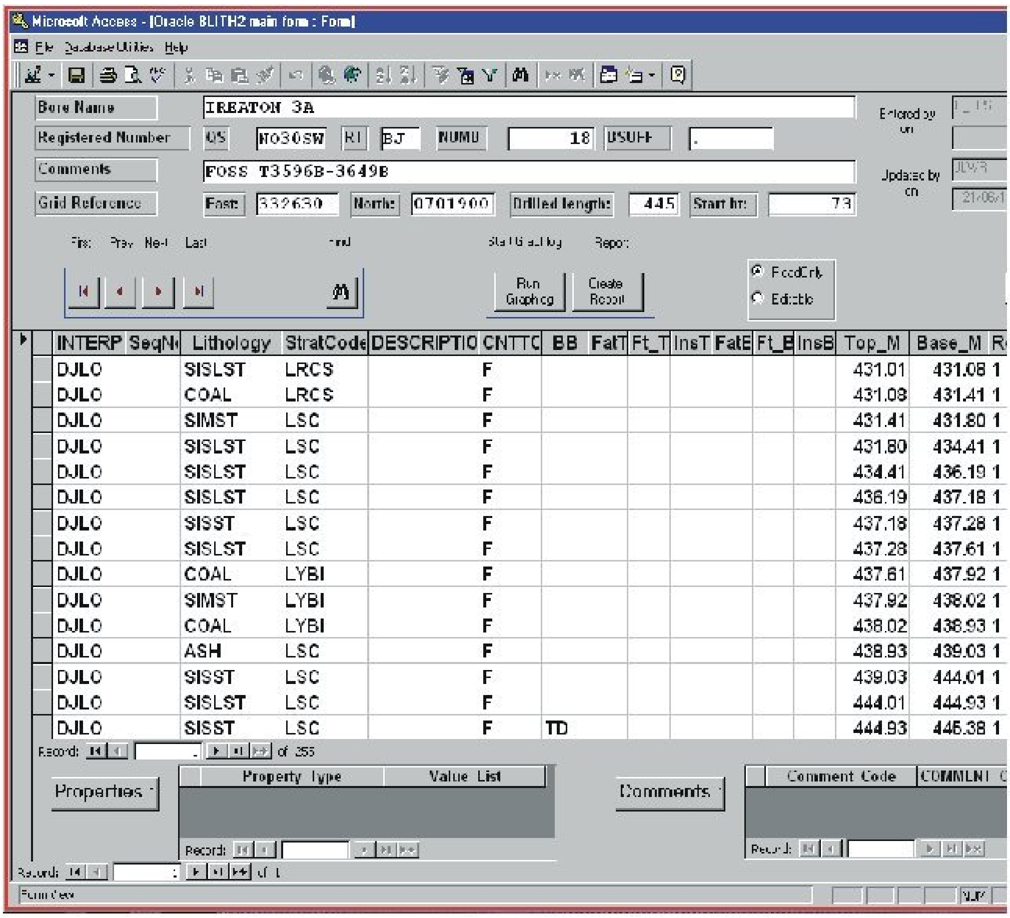
Comments From: All Reviewers Close

[m1] Simplify this by changing the word order.
[m2] Requires more substantiation. Suggest precede with quote from Peled and Adler (1993) and report views of other mapping agencies.

Fig. 2. "Red-lining" in editing a document. This enables reviewers to annotate and suggest changes without obscuring the original wording.

Some sections of a project document, notably the references and table of contents, may have contributions from all the authors, and all may take part in the editing process. With a large and complex document, it may be helpful to set up a formal structure for the sections of the document, to clarify where responsibilities lie and simplify the task of building a single coherent document. The **SGML** approach to structuring a document (E 6) is particularly relevant if it is to be archived. The SGML mark-up language separates content from presentation (specified by a style sheet), and thus makes it possible to present aspects of the work in different ways for different audiences. It also subdivides the document into identifiable sections, which can be cataloged and retrieved separately, and possibly reused in other contexts. The production of a hypermedia document might be considered, with the possibility of linking in maps, photographs, models, datasets and video records. The potential advantages are described in L 6.3 where the drawbacks of publishing in this form are also mentioned.

IT can also provide the means for integrating the data collected for various aspects of a project. A simple database can be built up using the tools available on the desktop computer. On-screen forms can be designed (Fig. 3) for entering data on any topic. Links between topics can also be created. For example, the results of a geochemical analysis could be related to the specimen from which the sample was analyzed, and this linked in turn to a description of a thin section cut from the same specimen. The linkage, however, must be part of the design of the investigation. The organization of the database (H 3) stems from the way in which the data are collected. The relationships between data items can be depicted on a diagram (Fig. 4) which shows types of data (entities), attributes and relationships. These **entity-relationship diagrams** can be quite complex, and can include data from many sources. The layout of a database can be generated from such diagrams using computer-aided support environment (CASE) tools. At the level of a project, however, a simple diagram should be sufficient, perhaps prepared on a computer drafting system to avoid the tedium of correcting hand-drawn diagrams.



Microsoft Access - [Oracle BLITH2 main form : Form]

File Database Utilities Help

Bore Name: IREATON 3A

Registered Number: QS NO30SW RT BJ NUMB 18 BSUFF .

Comments: FOSS T3596B-3649B

Grid Reference: East: 332630 North: 0701900 Drilled length: 445 Start ht: 73

Entered by on

Updated by on

First Prev Next Last Find Start Graphing Report

Run Graphing Create Report

ReadOnly Editable

INTERP	SeqNo	Lithology	StratCode	DESCRIPTIO	CNTTC	BB	FatT	Ft_T	InsT	FatE	Ft_E	InsB	Top_M	Base_M	R
DJLO		SISLST	LRCS		F								431.01	431.08	1
DJLO		COAL	LRCS		F								431.08	431.41	1
DJLO		SIMST	LSC		F								431.41	431.80	1
DJLO		SISLST	LSC		F								431.80	434.41	1
DJLO		SISLST	LSC		F								434.41	436.19	1
DJLO		SISLST	LSC		F								436.19	437.18	1
DJLO		SISST	LSC		F								437.18	437.28	1
DJLO		SISLST	LSC		F								437.28	437.61	1
DJLO		COAL	LYBI		F								437.61	437.92	1
DJLO		SIMST	LYBI		F								437.92	438.02	1
DJLO		COAL	LYBI		F								438.02	438.93	1
DJLO		ASH	LSC		F								438.93	439.03	1
DJLO		SISST	LSC		F								439.03	444.01	1
DJLO		SISLST	LSC		F								444.01	444.93	1
DJLO		SISST	LSC		F	TD							444.93	445.38	1

Record: of 255

Properties | Property Type | Value List

Comments | Comment Code | COMMENT

Record: of 1

Form View

Fig. 3. Form on screen for entering data. The form, part of which is shown here, carries information at two hierarchical levels – the borehole and individual beds. It is a convenient format for displaying the data, and for authorized users to enter or edit information using standard codes. British Geological Survey ©NERC. All rights reserved.

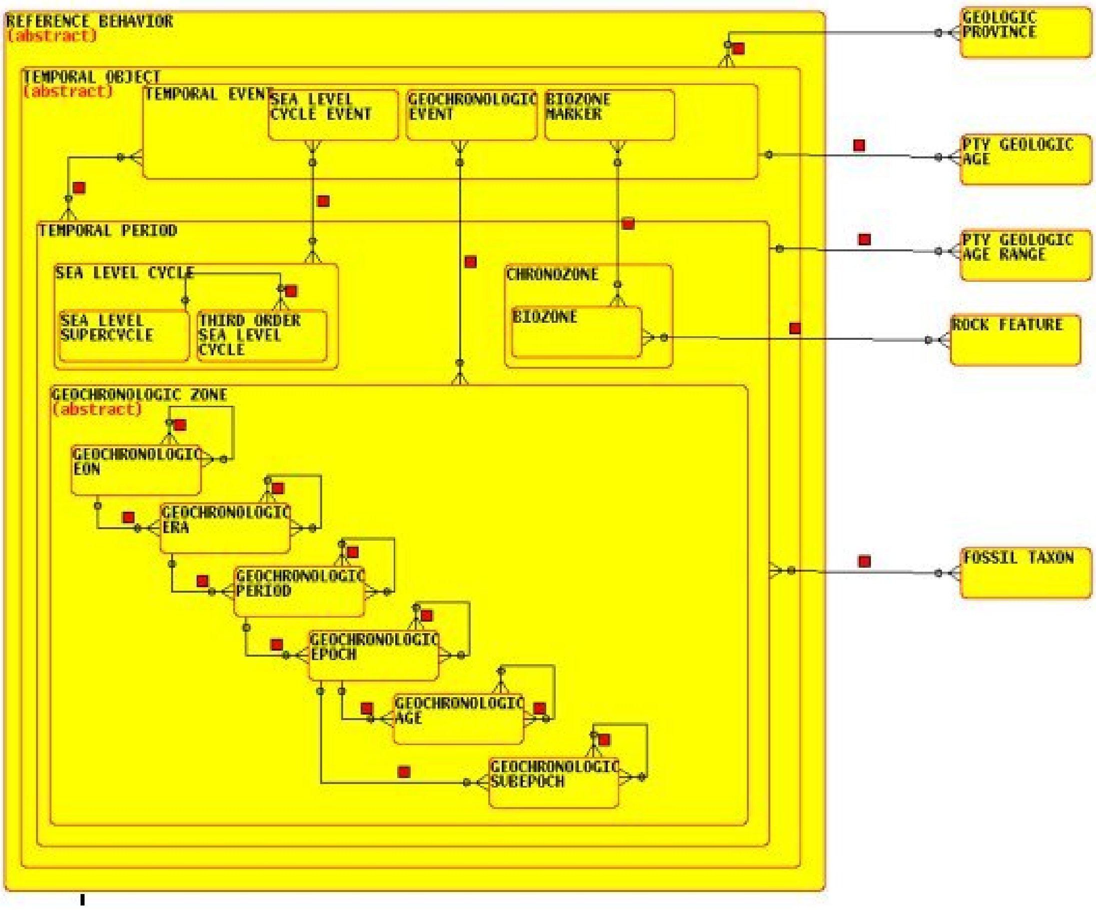


Fig. 4. Entity-relationship model. The entities are shown as boxes, in this example referring to geochronology. Aspects of their relationships are shown by the lines that link them. On pointing to the small box that appears beside each line, verb phrases appear that define the relationships. For example, each temporal period (top left) may be bound by one or more temporal event; each temporal event may bound one or more temporal period. Reproduced by permission of the Petrotechnical Open Software Corporation. More on the “Epicentre model” at http://www.posc.org/

Data are frequently stored in the form of **tables**, and can thus be treated as a spreadsheet. This structure can also be referred to as a flat file or a two-dimensional array. Quantitative data held as a table is known in algebra as a matrix (F 4). The obvious reason for this arrangement is that each column can hold records of measurements of a particular variable, and each row can hold the information for a different item. This assumes that the same variables are measured for each item. The variation within each variable can be studied separately, including perhaps their spatial distribution, but it is also possible to see how the different variables are interrelated (F 5). A number of different tables are required to cope with different topics, such as petrographic descriptions, lithological descriptions, geochemical analyses and so on. There can, however, be links between them. For example, the analyses may come from the same borehole, from the same location, or even from the same specimen. Care is therefore needed to ensure that the data records are not only consistent within tables, but also between tables (H 3).

The purpose of creating project documents is to make them available to others within or outside the project, and to organize the information for further analysis. IT opens up new possibilities of analysis, and formalizes structures for holding the data. These are considered later.

7. IT applications in the cycle of project activities

It is essential to think of IT support for projects from a number of viewpoints, and adopt the one best suited to the task in hand. It may help at this stage to look at the cycle of activities involved in a geoscience project, and indicate the types of IT support available for each activity. This may serve (at the risk of repetition) to remind the user of the available applications and how they fit together - a shop window of IT techniques where the potential user can browse and decide where to look further. They are arranged as an idealized set of activities (M 1) for carrying out a geoscience project (I 8.1), such as a gravity survey, preparing a soil map, or identifying a batch of fossil specimens.

The first activity might be to clarify the objectives of the project, determine the resources available, and plan its execution. The next activity could be to find existing, relevant information. Then data might be collected in the field or the laboratory. The data would be classified, analyzed and explained, perhaps by means of a computer model. The results would be presented, with visualization where appropriate. They would be discussed with others and their broad implications taken into account. They could then be reviewed, revised, edited as necessary, and published or otherwise made available to the intended audience.

Real life, of course, is not like that. Activities overlap and some may not be recognizable at all. The cycle of activities as a whole, and subcycles within it, may be repeated many times before the project is over. Initial results, for instance, may lead to revising the plan and calling for more resources. The scheme, which follows, is an idealized model with some features at least in common with a real project.

7.1 Planning, analysis and project management

An exploratory project by one individual may need little formal planning, ad hoc decisions being taken as the project proceeds. But a project using scarce resources and embedded in a larger investigation may require appropriate results on a tight time scale, and therefore need careful planning and rigid control. Computer support is likely to include word processing, spreadsheets and business graphics.

Communication can be assisted and formalized with programs specifically designed for project management. Methods include:

- Electronic mail and word processing for communication and preparation of project documents (D 2, C 3)
- Diaries, movement sheets and time planners to allocate staff resources, plan meetings and monitor progress (D 5)
- Spread-sheets to support costing and allocation of resources, such as staff time and equipment, and to monitor usage and costs (C 4)
- Gantt charts or critical path analysis to schedule tasks, identify milestones, monitor progress and adjust priorities (D 5)

7.2 Desk studies, literature search, archive search

The preliminary desk study assembles relevant existing material from available sources. Consider whether the value of old information justifies the cost of retrieving it, or whether collecting new information might be more cost-effective.

- On-line Public Access Catalogs (OPACs) can help with searching for references in your local library, or if need be, in major libraries throughout the world (H 2)
- Citation indexes can extend the search forwards in time from known sources (H 2)
- Searching the World Wide Web may yield useful information (E 4)
- Other workers in the same topic area may respond to e-mail or Usenet inquiries (E 4, D 2)
- Computer indexes to archives and repositories may be searchable remotely (H 3)

Much of this information will have been prepared by librarians and should be in a suitable form for adding to your own lists of references (H 2).

7.3 Field and laboratory data collection

Many instruments in the laboratory or in the field, including much geophysical and oceanographic equipment, will automatically deliver digital, computer-compatible records. Data collection methods may even be adjusted automatically to conform to a responsive computer model. A quick comparison of cost, accuracy and time-saving will show whether this is worth while. Some thought should be given to the ultimate use of the data, and to the interfaces that enable it to reach the point where it is needed (such as a database) in an appropriate form. The computer does not necessarily make this easier. A number of alternative routes to acquiring data might be considered.

- Rigorously organized data, say for the collection of stream sediments for geochemical analysis, or for description of shallow boreholes, might be collected with preprinted forms or with prompt sheets (C 5), and the data later digitized manually or mechanically.
- The same procedure can be followed, but entering data directly to a computer or data recorder in the field (C 5).
- Electronic theodolites and range finders and Global Positioning System equipment (C 5) can assist field mapping and locating instrument stations.
- The data may be recorded for later entry, or the map can be plotted, edited and stored electronically in the field (C 5).
- Points, lines and symbols can be drawn in the field over a conventional base map, an air photograph or a satellite image. They can later be scanned or manually digitized, and the distortions corrected by computer (G 1, G 2).

7.4 Explanation, classification, modeling

Although the intuition and expertise of the human brain are essential in developing explanations, IT can assist the process by assembling, codifying, manipulating, analyzing and presenting the supporting information.

- Descriptive statistics, such as the averages of measured values, can readily be calculated, and X-Y plots drawn to look at possible correlations (F 3).
- Multivariate statistics can be computed which may throw light on complex relationships that would not otherwise be revealed (F 5).
- Numerical taxonomy offers procedures, such as cluster analysis, for classifying large numbers of items on the basis of their measured properties (F 5).
- Explanations may involve computer models (F 3, J 2.3), particularly in areas like geophysics or engineering geology, where the underlying relationships can be related to the laws of physics.
- Data analysis of the entities investigated in geoscience, and their relationships, may lead to diagrams, drawn and edited on the computer, which help to explain the structure of the information as well as encouraging a more consistent approach (H 3).
- Explanations that would conventionally be presented as a written report can be given greater depth with hypermedia. Through access to additional background, such as video demonstrations, the reader can link the explanation to the supporting evidence (J 1.5).
- Techniques derived from studies of machine intelligence can formalize aspects of geoscientists' thought processes (L 5). These can be built into expert systems that can then apply the reasoning to other geoscience information.

7.5 Visualization, presentation

Geoscience is concerned with spatial processes and their interaction with geological objects through geological time and space. The importance of maps, cross-sections and block diagrams is therefore not surprising. Computer cartography plays a large part in the production of the maps. They can be regarded as an aspect of computer visualization, a subject that explores the application of graphical methods to the understanding of data.

- Bar charts, pie charts, and x-y plots (C 4) can help the user to grasp the relative frequencies and correlation of variables.
- Digital cartography and spatial models can show the pattern of variables in space, their spatial relationships and spatial correlation (G 1, G 2).
- Geographic information systems (L 4) and visualization systems (E 5, G 7) provide a more flexible means of displaying two and three-dimensional relationships than the conventional approach of examining and overlaying maps
- Hypertext and hypermedia systems make it possible to combine and cross-refer between text, images, models and map information in a more flexible manner (L 6).
- Portable display systems make it possible to present live demonstrations of multimedia to a large audience, through a suitable projector (C 6).

7.6 Reconciling information and aligning ideas

A significant part of the time spent on an investigation may be devoted to resolving conflicts between differing views, possibly within a project, possibly between ideas arising from different projects. The IT contribution to these debates is to provide discussion forums, with faster response and greater convenience, accuracy and global reach than conventional methods.

- E-mail (E 4), the Usenet (D 2), and the World Wide Web (E 4) are means of communication which meet different needs.
- The process of seeking the views of others, as in tendering for new facilities or in setting standards, can be formalized as Requests for Technology and Requests for Comment. A good example is the procedures followed by POSC (L 5).
- Digitized information from several sources, such as photographs, satellite imagery, and geological and geophysical maps, can be linked, adjusted to fit, compared and integrated on a computer screen (L 4).
- **Teleconferencing** allows a small group to see one another on screen and participate in the same discussion from different locations, or can make it possible for an individual to address a group of any size from another location. The advantage over a video recording is that the speaker can respond immediately to audience reaction and questions.
- IT encourages the separation of metadata and standards from other information (L 6.1), thus assembling key reference information where all can consult it. In this way, greater consistency of data should be achievable, and any disputes about nomenclature or standards can be placed immediately before the relevant authority or submitted to an appropriate forum.

7.7 Review, revision, editing

There are obvious advantages to scientific editors and publishers in receiving material by disk or e-mail. It can be forwarded without delay to referees for consideration or comment, without the cost and inconvenience of handling and mailing photocopies. Comments can be marked up as an integral part of the text (D 6), and alternative versions directly compared. The author can incorporate agreed changes without retyping the rest of the text. The publisher can pass the finished work directly to the plate-maker and avoid the process of rekeying with the inevitable errors and additional corrections that this must introduce. Most publishers must obtain or prepare computer-readable copy for their printer’s phototypesetters, and may also wish to make an electronic version of the paper available to customers as an alternative to paper (M 2.1).

Documents prepared within a project, and multi-author papers generally, can benefit from IT methods, particularly if the authors are geographically dispersed. E-mail can be helpful in exchanging ideas rapidly, but it is also possible to create project-centered documents (D 6) which are accessible to all the authors, with agreed protocols for reading, writing or amendment. Similar multi-author procedures for describing, drawing, reviewing and amending diagrams and maps are possible using GIS software (L 4).

Documents, including maps (G 1), that are subject to rapid change and development, may not be published conventionally, but instead an electronic record can be archived on the computer and kept up to date. When a copy is required, the latest version can be made available. Changes can be logged and earlier versions recreated if need be. In-house documents, and those with limited circulation, may never be published conventionally but can simply be stored on the computer for access on demand.

8. References

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