A PRELIMINARY REPORT ON A SYSTEMATIC AND MODULAR METHOD OF SURVEYING AND MAPPING

PETER MATTHEWS*
Victorian Speleological Association

Abstract

Problems with incompatible and unwieldy maps caused the search for a better system. The solution being tried, and still under development, is a practical implementation of the so-called "street directory" method, perhaps better called modular mapping.

The system produces all routine maps as modules 200 mm square on A4 sheets, and at a range of standard scales chosen to suit both the particular area and the type of caves. The boundary of each sheet is fixed, and is determined strictly from a metric grid standardised on for the area, and not on the present wanderings of any cave. The grid is preferably the Australian Map Grid or close to it, but may in fact be any grid decided upon if no A.M.G. control points can be established in the area. Maps at different scales are used to enable either a close or an overall view of the caves or the area, and also to act as key sheets for the next scale down.

The set of sheets can be thought of as an "atlas" for the area. Each new survey fills another gap in the overall mosaic. Non-standard maps for special purposes are still drawn as required.

INTRODUCTION

This paper deals with a mapping technique which is currently under development and evaluation by the Victorian Speleological Association (V.S.A.). It was devised and introduced because as club records keeper and cave surveyor I was most dissatisfied and frustrated with the handling characteristics, cost, difficulty and incompatibility of existing cave maps and mapping methods.

The basic design of the method was actually done in 1972 but then shelved because of commitments to A.S.F. Documentation and Handbook. However, over the last few years V.S.A. has been fortunate to have had an influx of members who were keen on mapping. They were also interested in trying out the new technique. Its implementation and refinement has therefore now been able to proceed without making any significant demands on my own time. This surveying and mapping has been ably led by Lloyd Mill and Tom Whitehouse.

A preliminary report is presented at this time to encourage others to try out the method and hence speed up further development of what we feel promises to be a most useful technique.

WHY CHANGE?

What is wrong with the existing method anyway? Two things are mainly wrong: large map sheets and incompatible maps.

*66 Frogmore Crescent, PARK ORCHARDS, Vic. 3114

MATTHEWS – MODULAR MAPPING

Few will deny the following problems with large map sheets.

Handling. Opening in a windy paddock; using underground; unfolding and refolding; fighting a map whose only aim is to roll up again; "Clear the whole table so we can open the map!" etc.

Copying. Large sheets will not fit on photocopiers so the tracing-and-dyeline method must be used. This restricts the number of possible copying locations, particularly free ones, and is quite expensive anyway.

Filing. Tracings should not be folded, so they must be stored either rolled or flat. Have you tried to find and replace a tracing in a roll of fifty or more when the sheets are all different sizes and the title block (if any) could be in any of the four corners? This might even drive you to try flat filing, but how do you flat-file at home sheets measuring two metres long or more? Whichever way you do it, it is likely to be a "pain in the neck", space consuming and/or costly.

Drafting. Drafting of large maps usually requires a proper drawing board set-up.

Publishing. Large maps are almost unpublishable within the normal budget. The alternative is a special re-draw to a small size. Photoreduction is usually unsatisfactory because it makes the lettering unreadable.

Incompatible maps means that although the existing maps of any given area might be quite good individually, each has been produced apparently without any awareness of the others, and as a result it is usually impossible or a great deal of trouble to integrate and use them in any report, presentation or submission on the area. The chances are you will need to draw up a special set and probably do some actual surveying, and all the while time is usually very short for the submission. Generally there will be a mix of scales (all "standard"!). You might be lucky enough to have the entrances interrelated by a surface survey, but there will probably be no clue as to the relative orientation of one cave to the other or any cave to the surface survey: they will probably all show "magnetic" north, but what they mean is "compass" north, and different compasses can easily differ by up to ten degrees. A ten degree swing at a radius of 1 km gives a positional error of about 175 m. This is a long way if you are digging a connection! It is also very discernable - even on a 1:100 000 map.

The aim then, was a mapping system which was easier to live with, and which automatically produced compatible maps.

THE BASIC SCHEME

The main characteristics of the method are:

1. All the routine mapping for a given area takes the form of an integrated set of map sheets each 200 mm square on an A4 sheet, and arranged together to form an atlas for the area.

2. The boundaries of each map sheet, that is, the ground coverage, are fixed according to a definite rule, and are determined from an agreed metric grid for the area. This grid can be any arbitrary metric grid but is ideally the Australian Map Grid (A.M.G.).

3. The set of sheets consists of several groups of standard scales arranged in a hierarchical manner. The smallest scale comes first and consists of a

single A4 sheet covering the whole area - the "top sheet". Then follow the other scales in order, finishing with the detail sheets at the largest scale. The number of different scales chosen, and their values, will depend on the type of caves and the mapping needs for the particular area. The smaller scale sheets also act as key sheets for the scale below them, for example, a complete set might consist of:

a sheet at 1:100 000 which is also a key to
a set at 1:5000 which is also a key to
a set at 1:200.

4. Because of its modular nature the atlas lends itself to being built up over a period of many years yet is useful right from the start. It can inherently cope with the fluctuating and random enthusiasm so characteristic of some caving clubs: each new survey fills one more gap in the overall mosaic. Maps eventually growing together from different starting points will automatically match up.

5. Only the squares which actually have caves or other features on them get drawn. Conversely, regardless of which way a cave extends, the mapper routinely starts a new sheet without needing any heart-rending decisions about its placement.

6. Each atlas has a single map number like an area map. Individual sheets have sheet numbers according to the coordinates at their bottom left-hand corner. Cave map numbers within an atlas follow the normal rules (A.S.F., 1974).

An example of how the sheets fit together is shown in Fig. 1. Its "highest" sheet is 1:5000:

At 1:5000, 1 mm represents 5000 mm or 5 m.
Therefore a 200 mm sheet represents 200 x 5 m = 1000 m or 1 km.

If we divide this 1 km square into a grid of 5 both ways:
each resultant square represents 1000 m/5 = 200 m.

If we now expand one of these 200 m squares on to a 200 mm sheet:
1 mm will represent 1 m or 1000 mm. The scale is therefore 1:1000.

Similarly if we divide this sheet into 5 both ways:
each resultant square represents 200 m/5 = 40 m.

If we now expand one of these 40 m squares on to a 200 mm sheet:
1 mm will represent 40 000 mm/200 = 200 mm.
The scale is therefore 1:200.

Each sheet therefore, besides being a map in its own right, is also a key sheet to the next scale down.

Although this particular example uses a grid factor (ratio of adjacent scales) of 5 in both cases, the grid factor can in fact range between 2 and 25.

The method described is obviously the "street directory" principle talked about in caving circles for the last ten years or so. All we have done is establish a clear and practical way of implementing that concept.

Two well-known maps which use a series of detail sheets with a smaller scale key sheet are Mullamullang Cave (Hill, 1966) and Mammoth Cave, Jenolan (Dunkley & Anderson, 1971). However both these differ in one important respect from the method described here - their detail sheets have a size and location uniquely selected to suit the then current shape and

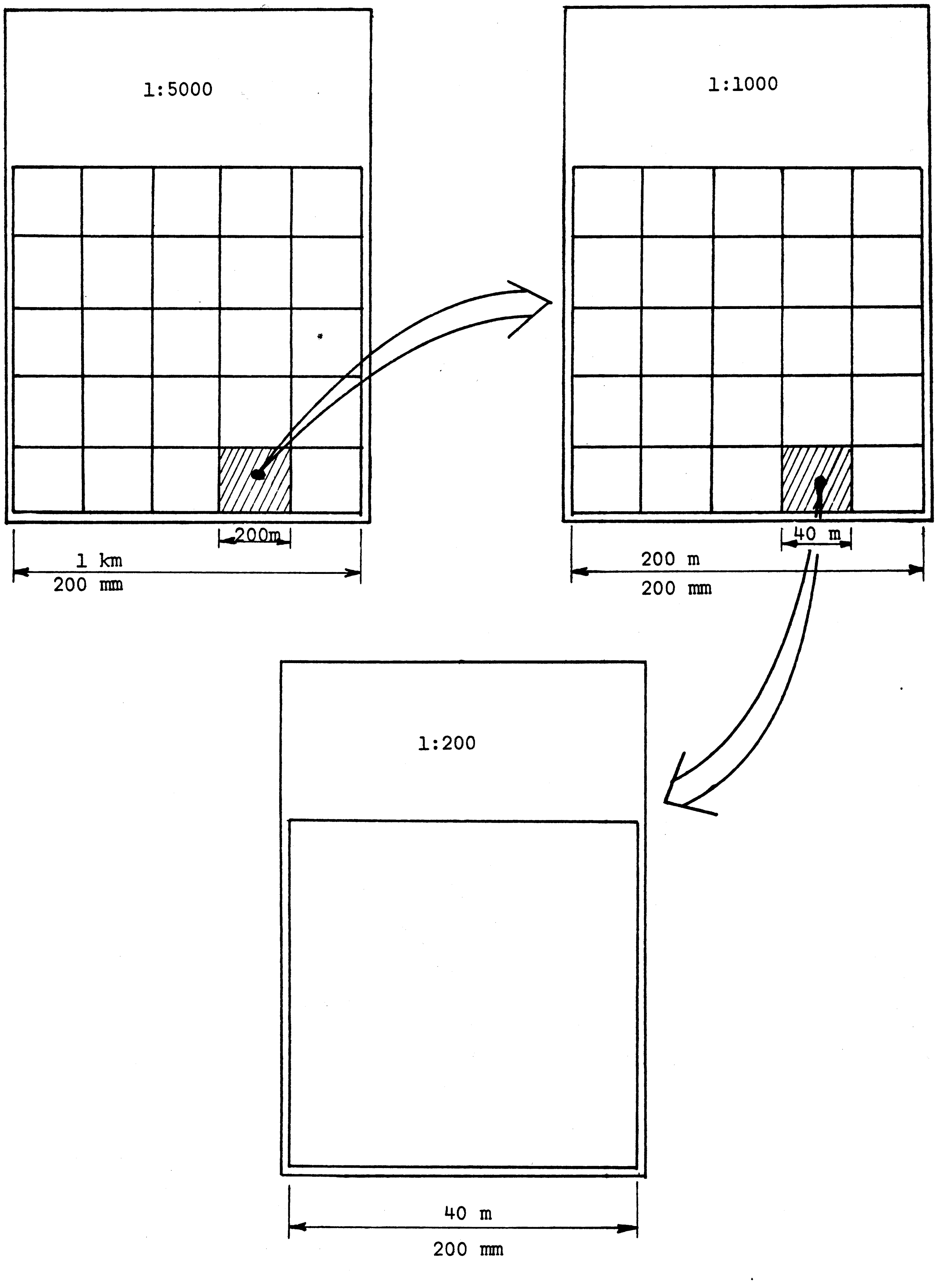


Figure 1. Example of scale relationships.

extent of the cave being studied, rather than being arrayed in a fixed and uniform grid.

While this method is more convenient and perfectly reasonable for presenting their respective cave, it is not very suitable (nor was it intended to be) for the routine long-term mapping of a whole area. The problems are:

- o future extensions and/or new caves could soon upset the careful initial placing of the detail sheets.
- o fairly important decisions continually have to be made about the placement of new detail sheets throughout the life of the project. It is certainly not automatic.
- o it becomes difficult to reference the arbitrarily placed detail sheets on an overall area basis.

When dealing with a whole area the uniform grid method of map sheets is better because all decision-making is done at the initiation of the project, and regardless of any new caves discovered or in what directions any cave develops:

- o the placement of all new sheets required is automatic and does not require reference to a central coordinator.
- o key sheets need no special notations on them to define or to reference lower level detail sheets - their existing grid automatically does this.
- o no constant maintenance of any referencing system is required.
- o adjacent maps always match up if they eventually join.

The only published example of a cave map using the uniform grid approach I am aware of is Flint Ridge Cave, Kentucky (Brucker & Burns, 1966), now of course part of the Mammoth Cave System. However that example used geographical coordinates (latitudes and longitudes) for its sheet boundaries, and hence had to use an additional and independent system for the numbering of its detail sheets. The detail sheets were 30-second rectangles (about 2400 ft by 3000 ft) at a scale of 1:3048 (1 cm = 100 ft), while the key sheet was 1:28 800 (1" = 2400 ft).

IMPLEMENTATION

There are two main stages: the initial setting up and routine use.

<u>The initial setting up</u>. The basic steps are:

1. Define the limits of the area. Include everything which could ever possibly be incorporated into the atlas for that area.

2. Decide on the scale for the top sheet. This should be the largest standard scale such that the whole area can be fitted on that one sheet. Standard scales will be found in Anderson et al. (1978:3). As much or as little of the A4 sheet as necessary can be used because the boundaries of the top sheet do not have to "obey" any higher sheet, that is, one is not limited to a 200 mm square. It is useful however if the boundaries align themselves with boundaries of sheets from the next lower level down.

3. Decide on the scale for the bottom (cave detail) sheets. This would commonly be 1:200.

4. Decide on the intermediate scales between these two. They should be chosen both with regard to their usefulness for that area and also should form convenient steps between the key sheets. Each scale should be a submultiple of the next higher scale, for example, 1:2000 and 1:5000 are not compatible but 1:2000 and 1:10 000 are. The maximum practical difference between adjacent scales is a factor of 25. Two examples of sets of scales are:

	Example 1	Example 2
top sheet	1:100 000	1:25 000
	5 000	5 000 1 000
detail sheets	200	200

If there is also a need for a scale which is not compatible, for example, 1:10 000 in Example 2 above, then this can be inserted in the set as an auxiliary scale but it will not form a part of the main key sheet series. Note that 1:10 000 would be compatible in Example 1.

5. Decide on a grid for the area and implement it. The preferred grid will be the A.M.G. because this is the standard grid, most people are already familiar with it, and it permits the use of existing official maps directly as part of the atlas; for example, the Buchan top sheet is an A4 cut-out from a 1:100 000 map, and its normal 1 km grid represents 1:5000 sheets.

However, the decision will ultimately be based on what control points can be established in the area. "Implementing a grid" really just means having (1) some permanently marked points in the area whose coordinates relative to some starting point or origin have been found by surveying and calculation, and, (2) a permanently marked sighting line for the area to define orientation (Anderson, 1978:5). Any subsequent cave surveys taking their coordinates from a nearby one of these control points and their orientation from the sighting line will automatically be properly located on that area grid.

The control points provide a "higher" accurate network from which the cave surveys are hung, and as such should be established before the actual drawing of any cave maps. The points can be established by triangulation, by traversing, or by a combination of both, such as traverses equalised between accurate triangulated points to establish strings of lesser accuracy control points.

High accuracy, however, is not essential to this modular mapping technique, although naturally it produces better results. Surface traverses done carefully with normal cave surveying instruments are perfectly adequate, provided closed loops are employed as a check and all compasses used are corrected to a common orientation.

Some typical situations are:

- accurate A.M.G. grid and control points established by theodolite and triangulation from official trig stations.
- approximate A.M.G. grid and control points by using landmarks identifiable on a topographical map.
- a purely local grid and control points of unknown relationship to the A.M.G., based on some convenient origin, and using a standardised magnetic north for orientation.

If accurate triangulation is being contemplated, a surveying textbook should be consulted to take advantage of established techniques for gaining maximum accuracy out of a given situation. *Surveying for field scientists* (Pugh, 1975) is a useful text.

Although a single sighting line with an agreed bearing is enough to define orientation of the grid, it is not enough to allow calibration and proper comparison of compasses. Some compass errors, such as pivot offset, are sinusoidal in nature, that is, the correction required depends on the direction being sighted. Because pivot offset direction will vary between compasses, comparing two compasses only on a single direction of sighting could give quite misleading results, depending as it does on the phase relationship between the two sine waves as well as the amplitudes. (We have found correction variations of up to two degrees around a prismatic and one degree around both our miners dials.)

Compass calibration stations should therefore provide several sighting lines spaced around the 360 degrees so that the correction-vs-bearing curve can be plotted and hence some intelligent decision made: one can then see what the average correction for that compass is, and either apply this average or apply the right correction per survey leg bearing. Note that reading both ends of a compass needle and averaging the two will remove the sinusoidal pivot offset error (and also bent-needle error), but in prismatic and Suunto compasses only one end of the needle is available.

6. Make up a folder for the atlas with a tab for each selected scale.

7. Prepare the initial version of the top sheet and any other high-level sheets which depend primarily on existing topographic maps

Routine use. The basic steps are:

1. Connect the cave survey to the surface control. The minimum requirement is a surface traverse to a control point or other known point. If better accuracy is required compass corrections should also be obtained, and if possible the cave survey should be strung between two or more control points, possibly with the aid of radio direction finding (R.D.F.) links. If calculated coordinate method (as opposed to the protractor and rule method) is being used, the whole cave should be calculated and equalised at this stage.

2. Mark the start of the survey in the right place on the right detail sheet. If a new sheet has to be made, see "Setting up new sheets" below.

3. Draft normally, using new detail sheets as required. If the protractor and rule method is being used any loop equalisations should be done now. If any of the detail sheets already exist from previous cave surveys, these existing sheets should be used. Elevations and cross-sections can be put on the A4 sheets either outside or inside the 200 mm square, or on auxiliary A4 sheets when necessary (use same sheet number but with dash-number added). The 70 mm strip between the title and the 200 mm square is useful for this purpose.

Normal paper can be used unless tracing or stability is specifically required. V.S.A. is trying out a polyester film with a blue drop-out grid showing 1, 5, 10 and 50 mm. It is not an expensive precision grid however. The brand is GAF "continuous sectional material" code G3002XC.

4. Transfer the cave silhouette or outline to higher-level sheets if appropriate. Generally the cave outline can be easily transferred square

by square by eye. For example, a 5 m square from a 1:200 sheet (A.S.F.'s recommended grid interval) is represented by a 5 mm square at 1:1000 and a 1 mm square at 1:5000. Most decent graph papers have 1 mm and 5 mm squares.

5. Assemble the sheets into numeric order within each scale and insert in the appropriate place in the atlas.

6. Register the existence of the new cave map in the club's set of A.S.F. Map Summary forms.

Setting up new sheets.

Sheet boundaries are determined by dividing the scale by five.

If this is strictly adhered to, all sheet boundaries will line up right through a set of key sheets.

Scale:	1:5000	1:1000	1:200
Sheet boundaries at every multiple of:	1000 m	200 m	40 m

With 40 or 400 m make sure you get the right multiples, for example:

	56 300	56 340	56 380	56 420	is wrong
but	56 320	56 360	56 400	56 440	is right.

If you are using other than 200 mm modules, then the factor to divide by is found by dividing your module size into one metre.

Grid interval is determined by dividing the sheet width by the number of times the next lowest scale fits into this scale, for example:

> If this sheet is 1:1000 and the next scale down is 1:500, then divide the 1:1000 sheet into (1000/500 =) two, both ways.

Strictly, the grid interval is determined by the sheet boundaries of the next lowest scale down, but for equal-sized modules (all 200 mm) the above rule holds.

If there are five or less grid lines across a sheet, then additional border ticks (not grid lines) should be added in accordance with, or as close as possible to, A.S.F. recommendations (Anderson et al., 1978:6).

Grid lines should be calibrated only in km or in metres as appropriate, and always including the respective "units" (km or m) digit.

Sheet numbers are given by the grid reference of the bottom left-hand corner of the sheet.

The high-order digit is always the 10's of km as is standard with map grid references, and the number of digits used is the minimum necessary to distinguish sheets within that scale, that is, the lowest order digit is the lowest one which changes from sheet to sheet, for example:

Scale	Size	Changes	Sheet number
1:5000	1 km sheet	kilometres	03.29 (3 km E, 29 km N)
1:1000	200 m sheet	100's of m	034.290
1:200	40 m sheet	10's of m	0340.2908

Different scale sheets with a common left-hand corner in any given atlas are usually distinguishable by the different number of digits, but not always. To avoid any possibility of confusion it is best to fill in as a matter of course the sheet number block in the title like the following examples (note these would not all be in the one set):

1 km sheet	400 m sheet	200 m sheet	100 m sheet	40 m sheet
03.29	032.296	032.296	032.296	0324.2968

A typical sheet format is shown in Fig. 2. The top margin should be at least 10 mm to allow for the gripping edge needed in some photocopiers and multilith machines. Some photocopiers are also a bit vague at the bottom edge, so at least the remaining 7 mm should be left there. The title strip shown is intended as a minimum identifier for each sheet - the main title details, possibly including schedules, should be on a special sheet(s) in the set. If cutting the sheet from gridded material as mentioned above, care should be taken to cause the 200 mm square to align with the 50 mm grid lines on the material. Use the opposite side of the sheet to the printed grid so that the grid will not be affected by erasures.

OTHER ASPECTS

sub-areas
special-purpose maps
standard cave location series
location security

In some large areas it might be preferred for convenience of working to handle some sub-areas separately. In this case all the respective sheets can be extracted from the main atlas and a sub-atlas formed just for that area, with its own individual top sheet. If the top sheet is not a standard sheet from the main atlas it should be given its own map number, but all the lower sheets will retain the original number of the main atlas as they are still really a part of it. At Buchan, V.S.A. has a separate top sheet for the Buchan Caves Reserve and surroundings; it is a vertical strip 2 km E-W by 5 km N-S up the centre of an A4 sheet at a scale of 1:25 000.

If for some specific presentation or submission the sheet boundaries are inconveniently located or the scale is unsuitable, then there should be no hesitation in producing a new special map for the purpose, using the standard sheets for the basis. This new map would have its own new map number. The modular mapping technique is primarily aimed at routine mapping, and while it will also satisfy many other mapping requirements it is certainly not expected to satisfy all.

The 1:5000 series of sheets can be very useful for general cave referencing, such as for a standard cave location series in an area. The scale is a convenient one for locations (1 mm = 5 m) and can still accept cave silhouettes. The sheets are also very identifiable, being the 1 km grid squares on official 1:100 000, 1:50 000 and 1:25 000 maps. V.S.A. is at present transferring the Buchan parish allotment map to these sheets so that fence-lines can be used (when they are in the right place!) to help plot cave locations.

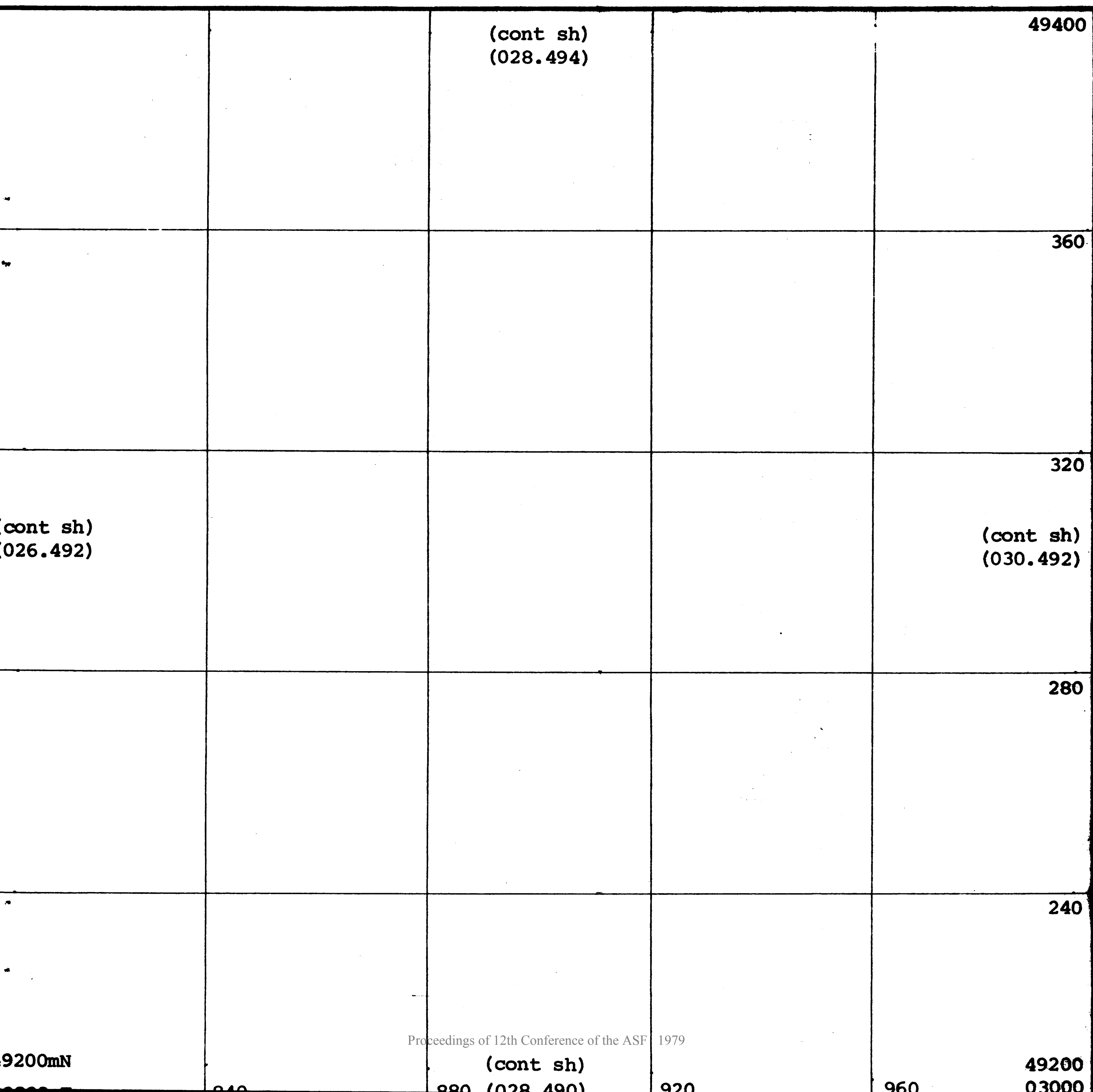
The question of location security is one we have not seriously looked at yet, although several possibilities come to mind - the use of an arbitrary grid or the suppression of high-order digits on an A.M.G. grid were mentioned by

V S A	Map No: 3B.VSA47	Atlas Title	1:1000	200m sheet
Rev 5: Computation 29.10.77		Subtitle for sheet or group	Grid: local	028.492

Squares are 40m 1:200 sheets.

FIGURE 2. SAMPLE MAP SHEET FORMAT.

Sheet Margins: Top 10mm
Sides 5mm
Bottom 7mm



Anderson et al.(1978:5), high-order A.M.G. digits could be replaced by an arbitrary code letter, the cave locations on V.S.A.'s 1:5000 sheets will probably be on separate overlays per sheet. This latter method will allow the 1:5000 sheets to be widely used for various purposes without revealing locations unless required. Even the very use of many sheets keeps the eggs in separate baskets.

DISADVANTAGES

1. The fixed boundaries can cause a small map to take up several sheets when it would really fit on one.

2. Modules 200 mm in size leave only a 5 mm margin at each side of the sheet. This can cause difficulties in some publications. However it is not practical to use any other module size with A4 sheets - key-sheet and other problems are caused.

3. Another consequence of the 200 mm size is that it is not possible to have formal sheet overlap; however I suspect overlap is a mythical advantage anyway on cave maps even if it is valid in street directories.

4. Drawing a cave at more than one scale is needed.

5. Some sort of surface control is needed. However this may actually be an advantage!

ADVANTAGES

1. The scheme provides a definite and simple long-term plan for club surveyors to work to.

2. All mapping is compatible. This means minimum delay when any submission has to be made.

3. It permits a rational and consistent presentation regardless of area size and level of detail required.

4. Cavers can survey where and when they like, and the results can still immediately fit into the overall scheme and eventually match up with adjacent maps - "One more square in the mosaic is filled."

5. All the A4 advantages:

o easy handling in the field and at home.

o easy and cheap filing.

o easy and cheap photocopying.

o easy and cheap drafting.

o easy and cheap publishing.

o fits on the cheaper computer plotters.

o fits in typewriters.

6. Makes infinite-sized wall-maps possible.

CONCLUSIONS

- The method does seem to be working.
- At last we feel we are on top of "the mapping problem".
- The advantages far outweigh the disadvantages.
- The method's main strength is in its ability to provide a scheme for the long-term integrated mapping of a whole area, not just of individual caves.

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