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The application of Geographical Information Systems to biological studies at hydrothermal vents

Maia TSURUMI
Department of Biology, University of Victoria, P.O. Box 3020, STN CSC, Victoria, B.C. Canada, V8W 3N5.
Fax: (1) 250 721-7120 - e-mail: mtsurumi@uvic.ca

Introduction

Geographical Information Systems (GIS) are software tools to process spatial information. The output of GIS analyses takes the form of maps, statistical summaries, and derived data sets. Such results can be used in other tasks such as modelling, hypothesis testing, or to provide easy access to attributes of the data for further analysis.

Most current GIS work on biological systems is in the fields of resource management and landscape ecology. There, it aids identification and explanation of disturbance patterns, effects of intervention on landscape structure, and neighbourhood interactions in natural populations. Outside of aquaculture, there is little application of GIS capabilities to biological systems in an aquatic environment. Wright (1996) and Wright et al. (1997) demonstrate GIS utility to geological studies of vents.

An important factor that enhances uses of GIS to hydrothermal studies is the inter-disciplinary nature of hydrothermal research. With the ever-increasing amount of oceanographic data collected in multi-agency, multi-disciplinary national and international research programmes, it may be more efficient to implement comprehensive data management techniques (Wright, 1996). Moreover, the difficulty and expense of sampling vents makes it crucial to maximize the amount of data available per dive. Maximal data extraction includes observations derived from dive tapes and photographs on geological, chemical, and biological features associated with venting. In GIS software, notes about these features can be entered and co-ordinated with point locations. These data and notes can be further organized alongside other notations such as what was sampled where, and by whom.

Another incentive to explore applications for biological work is the current use of GIS as tools for data collection and processing by some organizations, notably, the VENTS Program of NOAA. Post-dive, VENTS researchers use GIS software to provide maps of dive and camera tow tracks and produce tables of features associated with point locations from the tracklines. NOAA provides an interactive link to some of its GIS databases (World Wide Web, http://www.pmel.noaa.gov/vents/coax/gis_www.html). Off-site users have the capability to view, summarize, and make calculations on vent data held by various research institutions. A direct benefit derived from GIS organization of vent data is more expeditious delivery of such data to researchers involved in related investigations.

Presented here are partial results of a GIS application to a temporal study of venting on North Cleft Segment, Juan de Fuca Ridge (Fig. 1). The goal is to illustrate the use of this GIS software as a supplementary tool for analyses of temporal change and succession at vents.

Background on North Cleft Segment

In 1986 and 1987 two distinct megaplumes were discovered over North Cleft Segment. Modelling of the dynamics of both plumes was consistent with the sudden expulsion of fluids from a hydrothermal system (Embley et al., 1994). Towed camera and submersible observations located extensive diffuse venting and several black smokers between 44°53'N and 45°03'N (Fig. 1). North Cleft was visited from 1988 until 1995 by camera tow and submersible. In 1990, submersible observers found areas of dead tube worms and moribund vent communities; the high temperature vents remained vigourous. By 1991, diffuse venting had ceased along this part of the segment. In 1994, a new vent on a recent lava mound was located but venting remained absent elsewhere except at high temperature chimneys.

Using GIS to document temporal change

The GIS software package used in this analysis is ArcView®2.0 by ESRI™ which operates in the Microsoft® Windows™, Apple® Macintosh®, or UNIX® environments.

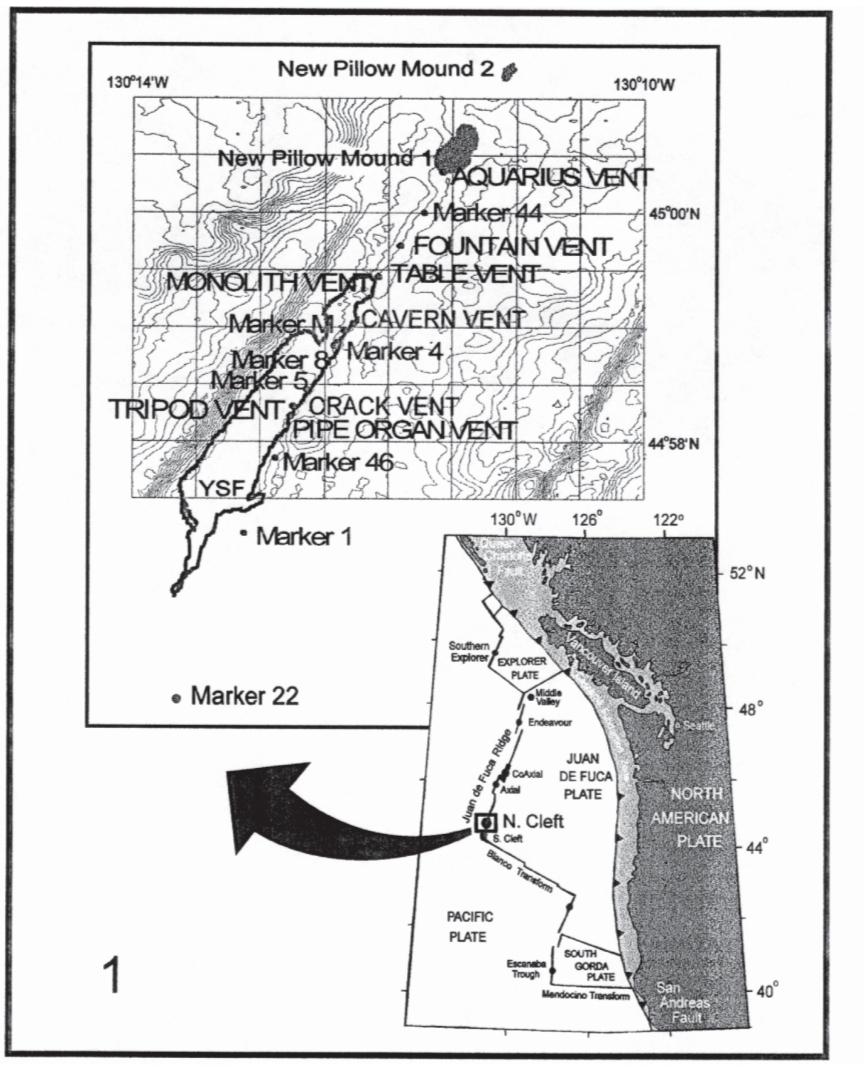


Figure 1. Location of the Juan de Fuca Ridge, showing surrounding tectonic features. Inset shows a close-up of the vents, geological features, and bathymetry of North Cleft segment. The contour intervals are 10 m.

Some of the tasks possible with ArcView include: 1) mapping, 2) displaying data from other GIS software databases, 3) displaying tabular data, 4) querying/searching/ manipulating attributes of any features associated with a map in the database, 5) summarizing and generating statistics on the attributes of features associated with a map, and 6) creating charts to show the attributes of features. In addition, there are ways of customizing ArcView to suit specific work needs.

The series of maps presented in Fig. 2 (a-d) show how information on the temporal state of venting on N. Cleft can be displayed using this GIS mapping program. These figures were produced by ArcView using data from the NOAA GIS database and from review and annotation of all the dive tapes, dive logs, and still photographs available from N. Cleft from 1988 until 1991. Within ArcView, each feature is mapped as a separate coverage called a “theme”. Therefore, on Fig. 2a-d, the bathymetry is one theme, the markers/vents locations another, the presence of bacteria yet another, and so on. These themes are then layered to produce a map. This method is a qualitative means to convey the concept that at N. Cleft diffuse venting seemed to peak in 1988 and to be in rapid decline by 1991.

ArcView tables are a convenient way to store data associated with a map. These data can be manipulated statistically in other programs by exporting the ArcView attribute tables (Fig. 3b). Quantitative biological estimates can be made on the areal coverage of tube-worms and or bacteria by using the same data that produced these maps. Basic statistics are possible within ArcView, but I found that

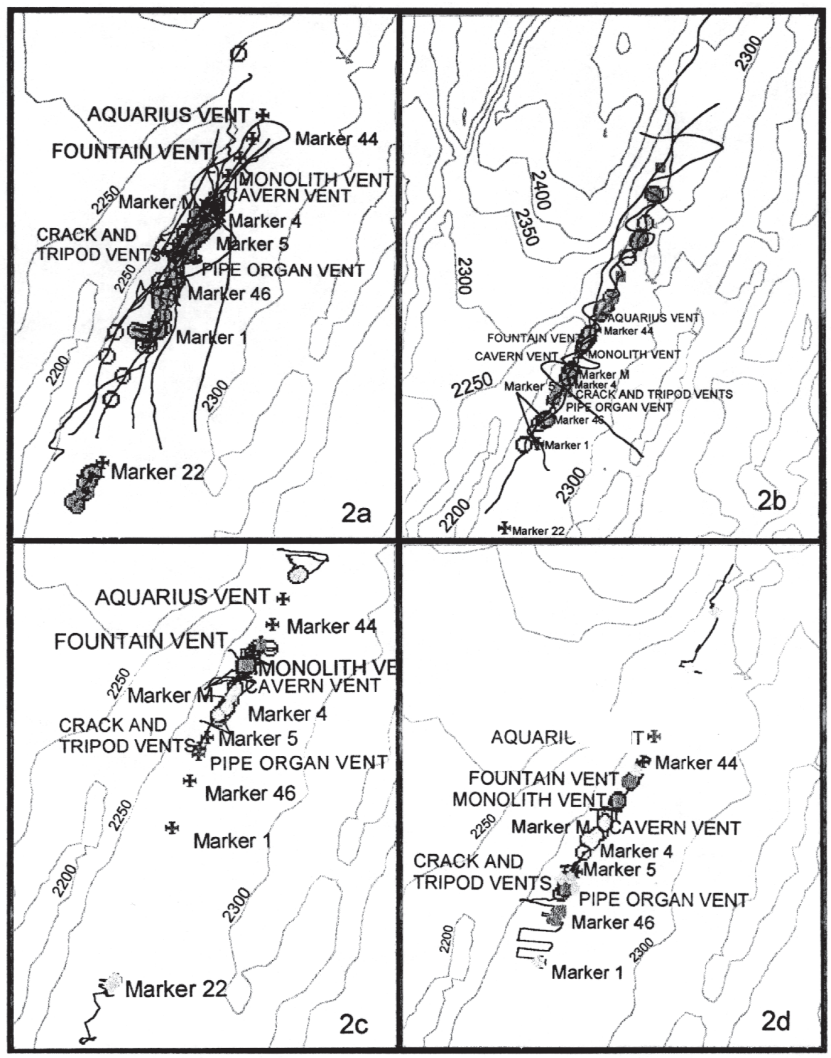


Figure 2. a-d show the temporal changes in venting extent from 1988 to 1991 at North Cleft Segment. a: 1988 *Alvin* and camera tows. b: 1989 camera tows. c: 1990 *Alvin*. d: 1991 *Alvin*. The contour intervals are 50 m. Vents are shown by the Maltese crosses; high temperature vents in upper case and low temperature vents in lower case. Open circles indicate areas with bacteria. Dark grey squares indicate areas of tube-worms. Light grey stippled diamonds indicate areas of dead tube-worms. Black lines are *Alvin* and camera tow tracklines.

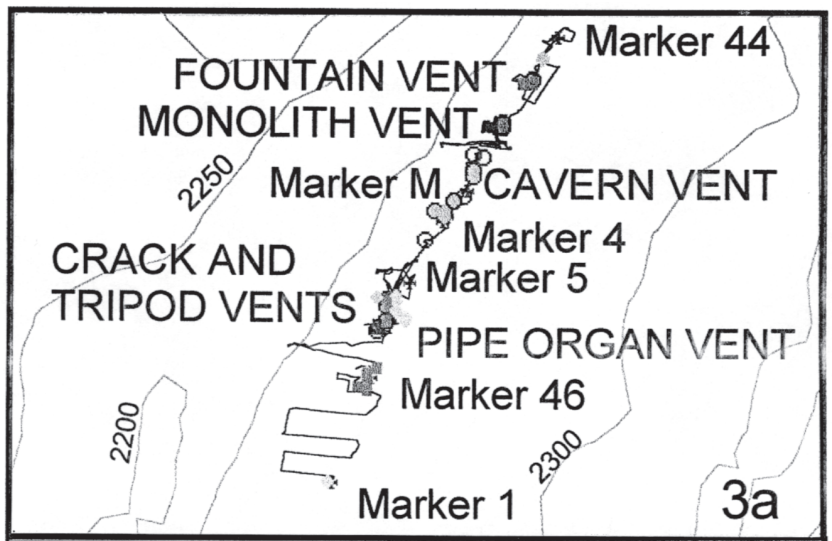
summary statistics were more easily generated by using Microsoft® Excel™.

Hot linking to other files is the facility in ArcView that allows access to other data sources or applications by clicking on a feature. For example, one could zoom in on one point location of an ArcView map and select one of the data points (e.g. the tube-worms themes) to display a picture of that site, access a document or table describing it, or even play a video showing it (Fig. 3a-c).

Conclusion

With respect to its potential as a tool for analysis, ArcView is an elegant way to display and inventory data about temporal changes in venting. At present however, it is unlikely that GIS will penetrate far into the spatial analyses domain of vent work. GIS was not intended in its inception to answer a "How is..?" type of question, but rather to answer static problems such as "Where is..?" or "What is..?" (Ball, 1994). The ability to handle time-dependent data (i.e. data in four-dimensions) is important for modelling such a highly dynamic marine environment as hydrothermal vent sites (Kucera, 1995; Wright, 1996) and as yet GIS generally lack three- or four-dimensional display and analysis capabilities.

For the purposes of the work on temporal changes at North Cleft Segment, ArcView is a useful application, supplementing descriptive and statistical analyses of change



Name	Dtime	Latitude	Longitude	Htl1_sec	Htl2_on
ALV2076	217.4767	44.96123	-130.217	0	5
ALV2076	217.4879	44.96050	-130.218	0	2
ALV2076	217.4906	44.96048	-130.218	0	4
ALV2076	217.4913	44.96047	-130.218	0	5
ALV2076	217.4920	44.96050	-130.218	0	5
ALV2076	217.4927	44.96050	-130.218	0	6
ALV2076	217.4969	44.96078	-130.218	0	3
ALV2076	217.4990	44.96048	-130.218	0	2
ALV2076	217.5004	44.96017	-130.218	0	2
ALV2076	217.5010	44.96012	-130.218	0	1
ALV2076	217.5552	44.95200	-130.219	0	2
ALV2076	217.5573	44.95223	-130.219	0	5
ALV2076	217.5608	44.95265	-130.218	0	6
ALV2076	217.5615	44.95278	-130.218	0	6
ALV2076	217.5622	44.95288	-130.217	0	6
ALV2076	217.5629	44.95275	-130.218	0	6
ALV2076	217.5642	44.95257	-130.218	0	3
ALV2076	217.5649	44.95225	-130.220	0	2
ALV2076	217.5663	44.95215	-130.224	0	3
ALV2076	217.5684	44.95210	-130.224	0	3
ALV2076	217.5712	44.95203	-130.224		
ALV2076	217.6024	44.95188	-130.218		
ALV2076	217.6122	44.95177	-130.223		

3b

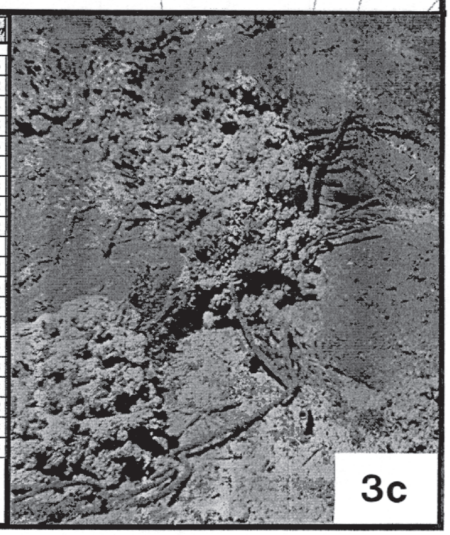


Figure 3. a-c show an example of "hot linking" within ArcView. By clicking a point location on 3a, various data associated with that point location can be accessed. a: State of venting on a portion of North Cleft segment in 1991. b: An example of an ArcView attribute table with data associated with the map in 3a. c: A photo of the vent area at Marker 1 in 1991.

in the vent communities, on this part of the Juan de Fuca Ridge. The ability to use this GIS software to augment work on the temporal ecology of North Cleft is a direct result of the effort NOAA has put into developing a database of seafloor maps of North Cleft, which function as a convenient baseline from which to work.

Acknowledgements

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