CARTOGRAPHIC FEATURE CODING

BRUCE D. WOOD *and* DAVID H. DOUGLAS, *University of Ottawa, Ottawa, Canada*

INTRODUCTION

THE FEDERAL GOVERNMENT of Canada, and other local and provincial levels of government and industry, are in the process of encoding spatial data in digital form. A classification of topographic features has recently been proposed by the Canadian Council of Surveying and Mapping as a national standard. This standard, if adopted, will basically become the interchange linkage for all of the digital data collected by the Topographic Survey of the Surveys and Mapping Branch. Topographic Survey is, and has been in the process of digitizing terrain information since the 1960s. One of its present goals is to digitize map data of the whole country at the scale of 1:50,000. An investigation of this classification is, therefore, extremely timely. Governments within Canada, of course, are not the only ones at, or through, the threshold of providing map data in digital form. Indeed the whole problem of exchange of spatial information in digital form between governments and between the private and public sectors is looming monstrously on the information processing horizon.

The problems of spatial information technology exchange can be classified into four levels, elucidated by Witiuk (1976) as the conceptual level, the algorithmic level, the systems level and at the final results level. Seen in this context as occupying the lowest of the four may be misleading, in that, especially with spatial data,there are a host of conceptual problems with data which are easy to underestimate, and easy to discount when others complain of having them. This may explain the lack of attention given to data exchange. At a very basic level there are a host of technical standards regarding EDP mediums, formats, self-defining headers and codes that must be developed and adopted, but these problems, although of concern, can be considered to lie largely outside the realm of cartography and within the fields of electronic data processing. Within the scope of cartography, the main concerns are those regarding data structure and the encoding methods for feature representation, and whether the features recorded are fundamentally the geographic phenomena themselves, or recordings of the traditional graphics utilized on paper maps to represent the geography.

HISTORICAL BACKGROUND

The problems of exchanging spatial data have come to the forefront of spatial information processing only recently, however in the broadest sense there has been a recognized need and an increasing attempt to exchange spatial data for over twenty years: Sparks, Guttenberg, Anderson, Clawson and Stewart to name but a few. These early commentators from the planning profession suggested that an important step in the right direction would be to develop a uniform land use classification. Two major handicaps they identified were: 1 the incompatible classifications and differing definitions of terms; and 2 the lack of measurement (Sparks, 1958, p. 175). Similarly, Guttenberg (1959, p. 143) noted that, since further progress in planning and planning research depends on exchange of empirical findings, it is especially important for planners to have a common language, a language so precise as to leave little room for misunderstanding. Anderson noted that the basic problem in the entire land use field is one of developing a classification with definitive criteria for separating the various classes that will give objective and repeatable results for any area being studied. A major work by Clawson and Stewart (1965) found that accurate, meaningful, and current data on land use are essential if public agencies and private organizations are to know what is happening and are to make sound plans for their own future action. At this early date they proposed that to overcome comparability problems over time and space, data on land could be transferred electronically to another point of use very quickly. 'Thus it would no longer be necessary that each point of use have its own storehouse of land data in the form of tabulations, publications, maps etc., but rather, data obtained in one place or by one agency could be stored ready for use by anyone quickly and inexpensively.' Is this not the basis of spatial data transfer in the digital era?

The problems associated with, and the importance of improving our ability for, spatial data transfer are today accentuated by the fact that more and more government agencies, universities and private industry are making use of the computer for storage, retrieval and analysis of spatial data (Linders). Often, however, much data are collected, massaged, and stored without careful thought as to what other uses the data might be put. Several diseconomies associated with this phenomenon include the simple (but expensive) fact that 1 often spatial data are not readily interchangeable (Yan et al.); 2 resources and accuracy are lost in the duplication of data collection and/or the extended efforts required to transform or regenerate data in order to use it; and 3 any real benefits derived from using the computer (such as timeliness, efficiency and/or replicability) are lost to the costs associated with outdated, incomplete and inaccessible data (Interministerial Committee on Geographical Referencing 1978).

Problems of exchange are increasingly being met by governmental committees established for the purpose. One of the earliest experiments in Canada was the formation of the Inter-Agency Spatial Data Transfer Committee which grew out of the less formal National Capital Geographic Information Processing Group of 1975. The Alberta Government, wishing to avoid the chaos of multiple development of incompatible systems endured by earlier entrants to the field, set up the Land Related Information Processing Systems Coordination Project (LRIS) in 1978. Similar problems of exchange were recognized in Ontario, where, of sixty-four geographical referencing systems in the Government '... it would be difficult if not impossible to transfer data between these systems without major modifications to most of them' (Interministerial Committee). One objective of this Committee on Geographical Referencing was to develop standards and specifications which could be incorporated into municipal, provincial and federal information systems in order to expedite the transfer and correlation of geographically referenced data with one of the prime concerns being the establishment of an acceptable grid reference.

Similar concerns expressed by the Report of the (Canadian) Task Force on National Surveys and Mapping revealed that a basic need at this time is the design and adoption of criteria for the storage, accessibility and exchange of digital spatial data among federal and provincial departments and agencies, utilities and the private sector. The Task Force noted that the most pressing need is the formulation and adoption of standards for the communication of data. Of course, other countries are also facing the same standardization issues and problems in similar ways. The ACSM National Committee for Digital Cartographic Data Standards is a case in point. All of these attempts to solve the data transfer problem by committees illustrate the importance of the subject, and indicate a measure of the intractability of the problems being faced.

THE FEATURE CODING PROBLEM

There are many aspects to the handling and transfer of spatial data. This short note attempts only to provide some definitive ideas on how the feature coding problem might be resolved. The digital description of a cartographic or geographic feature can be considered as having two components, a geometric description and an attribute description. The geometric description has been given rather more attention. Methods for numerically recording points, lines and surfaces have been developed to a high degree of sophistication. Topological structuring of data to represent networks, graphs, solids, etc., to enable more efficient searches and manipulations, to compute properties from the geometry and to generate interesting graphics are also well represented in the literature. Geometric description problems seem to offer more interesting challenges. This may be because of the multi-dimensional aspects of geometric data, but also because when a technician or researcher is working with a data-set it is usually of one kind of feature. It is a file of contours, or a digital elevation model of temperature, etc., and this fact reduces the importance of its identification since its description will be understood or may be noted with the written description of the file. Of course the importance of self-describing data grows when one considers mass exchanges amongst governments and between the private and public sectors.

Problems of devising self-describing codes for objects and their non-spatial attributes at first seem straightforward and perhaps rather obvious. If road maps are composed of subsets from fifty-seven different symbols, simply create a table of fifty-seven items, number them and include an integer from 1 to 57 with each geometric feature in the digital file. Sort them alphabetically before numbering them if it is expected that the list will be examined frequently by eye. Even the addition of that 58th feature need not cause excessive concern. Add it on the end, or assign to it a decimal number to insert it into its proper alphabetical place, or redraft the code attaching a flag to the data identifying the specific code list to employ. In fact, do not even use a numerical code, but rather let the alphabetic words themselves or mnemonic short forms act as the code. All of these solutions are indeed employed, but it is apparent that even at this level the problem is losing its trivial innocence. Contrasting with a road map series, a topographic series may have from 1,000 to 2,000 different types of features. The mere compilation of the list of things appearing on a whole series for a country the size of Canada is no trivial task.

As in traditional cartography, the topographic map forms the basic building block for thematic and special purpose maps. One contention is that the general purpose topographic feature classification adopted will have major implications on the level of geospatial analysis permitted with the encoded data in the future. This contention stems from three facts. Firstly, automated cartography is not limited to the automated drafting of maps but extends into the area of cartographic data services from which a wide variety of graphic products, both stored cartographic information as well as derived information, can be produced (displayed) on demand. Secondly, the topographic map, either directly or after scale and projection changes, provides the foundation for many of the published maps used increasingly by the many sciences and professions who demand terrain information (Zarzycki, Harris and Linders, pp. 1–9). Thirdly, any feature coding standard, if it is done well, may provide the foundation of other systems created for and by specific users, whether or not they utilize data from a Governmental Survey. This may create opportunities for transfers from non-governmental agencies, such as utility organizations, to the government for generalization to Survey needs.

Linders (1978, pp. 188–191) notes that the development of a system for mass exchanges implies a taxonomy or classification of information with the objective of providing a single logical system for the storage and management of all land mass data. He suggested that such a system must incorporate detailed information for: feature location; feature taxonomy (the component elements of the data base must be uniquely classified through a data dictionary); attribute data (for further differentiation of features); relational data; and representational information (i.e., the exact depiction of each feature element in terms of its graphic components).

Taxonomy implies the ordering of information into a hierarchy to develop understandings of phenomena, but in the context of cartographic or geographic features, to allow groupings on the basis of the criteria used to form the hierarchy. A tree-structured ordering, for instance, could be made to allow a multitude of alias names or ordered groupings to result in the same classification. A digitizer operator may identify a feature with the words 'thermonuclear power station,' while another might say 'atomic electricity plant.' Logical algorithms could be constructed to automatically recognize both as being the same thing placing them into 'building: industrial, electric power generation station, thermal, nuclear'. The coding system should be such as to allow such algorithms to be written. On the retrieval side, like objects should be sequentially groupable on the basis of their identification or their properties. Beyond being possible to call all 'jails and penitentiaries,' it should be possible to call all 'two to six lane roads,' obviating the need to enter 'three', 'four', and 'five'. Furthermore, groupings across properties should be possible, such as a call for all 'abandoned' things. These capabilities would be prerequisites for a system that would automatically filter and generalize data to prepare a file for maps at different scales. 'Extract all information on transportation suitable for a map at the 1:4 million scale.'

TAXONOMY AND CLASSIFICATION

Through the illustration of classification principles, one transcends various realms of knowledge. Dolby (1979, pp. 167–193), for example, distinguishes the logico-mathematical theory of classification of the sciences, (e.g., the classification of the objects of study within a particular science as in the biological classification of living organisms), from related practical classifications intended for particular purposes, such as library science.

Taxonomy basically deals with the classification of all living things according to observed natural or hypothetical relationships, or both. The idea of taxonomy was first made explicit in the history of western thought by Aristotle in his *Organon and Metaphysics.* The ruling principle is that the highest genus is divided by means of differentiae into subaltern genera, and each of these is then divided and subdivided until the ultimate species is reached. This principle has been handed down through the Stoics, Porphyry and the Greek commentators to Linnaeus, from whom it passed into modern biological usage (Peck, 1965, pp. v–viii).

Grigg notes that classification, defined as the grouping of objects (elements) into classes (sets) on the basis of common properties or relations, is a necessary preliminary in most sciences, and it is often argued that the state of classification is a measure of the maturity of a science. Although classifications can be built on various principles (morphologic, generic, temporal, spatial, quantitative, etc.), all must follow certain general and unalterable laws of logic: 1 the sum of classes must be equal to the scope of the classified generic concept; 2 only one classificatory criterion should be used within any one level of classification; and 3 a classification must not skip logical levels (Armand, 1965, p. 22).

The logico-mathematical theory of classification coincides with what, in the mathematical theory of sets, is called a partition. A division of a set of objects into subsets is a partition if and only if: 1 no two subsets have any elements in common; and 2 all of the sets together contain all of the members of the partitioned set. To the rules that a successful classification must be mutually inclusive and collectively exhaustive, Wynar (1980, pp. 400–402) adds that notation must be flexible if the classification scheme is to be current. The classification scheme must also employ terminology that is clear and descriptive, with consistent meaning for both the user and classifier. Although most traditional classification schemes are based on a logical division of the universe of knowledge, by contrast, Wynar states that computer-based classification systems are empirical and descriptive, attempting to develop thesauri with but one thing in common – a set of descriptors well suited to manipulation.

The following list of ten principles that should be taken into consideration when designing a classification system was proposed by Grigg (1965, p. 481).

1. classifications should be designed for a specific purpose;
2. objects which differ in kind will not easily fit into the same classification;
3. classifications must be changed as more knowledge is gained about the objects under study;
4. the differentiating characteristics should be properties of the objects classed;
5. in logical division, the division should be exhaustive;
6. in logical division and classification, the species or classes should exclude each other;
7. in division, the division should proceed as far as possible upon one principle;
8. the principle of division must be important for the purpose of the classification;
9. properties which are used to divide or classify in the higher categories must be more important than those used in the lower categories;
10. the logical consistency of the hierarchy will only be maintained if rules five through nine are observed.

Classification obviously is very complex, based on logical principles which necessitate much conceptual foresight in both design and implementation. Problems inherent in any classification system vary in extreme depending on the initial objectives of that science or discipline. These problems are more manifest in a general purpose classification because of the attempt for broader applications.

CARTOGRAPHIC FEATURE CLASSIFICATION

The following is a very brief summary of a systematic analysis of several significant cartographic feature codes now in use, or in the proposal stage. The objective was to identify an optimal code that was inclusive, flexible and open-ended, that could possibly be used in a general system, or at least to identify principles towards the development of one. Review, analysis and evaluation of these systems placed emphasis on identifying overall strengths as well as pinpointing weaknesses and faults.

The U.S. Geological Survey Attribute Codes for Digital Line Graphs (1981) consists of approximately 486 7-digit real number codes arranged into 11 base categories by the point, line or area characteristic of the feature classified. The implementation of parametric, multiple feature and coincidence coding, the integration with other codes (such as FIPS, Public Land Use and State Plane coordinate Zones), and the use of nodes as feature types to identify changes in feature classification are important assets. The main disadvantage relates to the geographic description of the feature being buried in the feature code itself.

The DMA Catalog (1977) shows us that it is possible to integrate a feature classification to facilitate the needs of three mapping centres. The schema is a hierarchy of 10 categories, 34 sub-categories, 97 classes and 753 features (each of which is identified by a 4-digit integer code) as well as the extensive use of attribute lists (3-digit integer codes). Its main advantage is the flexibility in feature description afforded by the attribute lists. Its main disadvantages relate to the inconsistency in feature description (some features are tersely described, others are but lengthy conglomerations of modifying concepts), and the double coding of similar attribute values with different 3-digit codes. The concept of 4-digit integer values, because of its limitation of 10 items per any digit, will have to be modified to allow expansion in future versions of the standard.

The Australian Standard (1981), consisting of 657 4-digit feature codes, is quite similar to the DMA system but much simpler in terms of information provided. It lacks the comprehensiveness of the DMA catalog, particularly as this relates to feature modifier 'lists'. The fact that feature modifiers must be user defined offers some flexibility, but the fact that they are not standardized reduces their importance as far as a national data base is concerned. A similar version of the standard, provided by Systemhouse Ltd. of Ottawa, is in place in India. The concept of table-driven parameters as well as certain relational aspects of the code merit investigation.

The Ordnance Survey Code (Digital Data Supplied to their Customers) is unique for its apparent simplicity. Quite likely, the sophisticated aspects are transparent to the user. The Ordnance Survey supplies the graphic program with their digital topographic data. Parent scale series are 1:1,250, 1:2,500 and 1:10,000 for urban, rural and wilderness mapping respectively.

The Canadian Hydrographic Service Feature Classification, designed purely for paper chart production via a digital data base, provides some good ground for comparison with the Canadian topographic feature classification, even though the two classifications are incompatible. C.H.S. store their attribute data in a file separate from the geometric data.

The Canadian Topographic Feature Classification consists of 1558 10-digit alphanumeric codes, hierarchically arranged according to the levels of class, category, feature and attribute. As a first draft for a national standard, it has made an exemplary and fundamental contribution by compiling all items which occur on the traditional paper graphic for the whole series of Canadian topographic maps. As a national standard however, notable weaknesses which require re-examination include:

1 reduction of data measurement level, sometimes arbitrarily dictated by alphabetical arrangement; 2 fixed limitations regarding expansion of new types of features (either the features fit with the structure as proposed or they won't be able to fit); 3 unreferenced redevelopment of classifications highly refined by other agencies, such as the SIC code; 4 fixed limitations, by its structural design, concerning relations (combinations) of geographic descriptors; 5 a reliance on an arbitrary definition of what is defined as topographic and what is thematic, thereby artificially reducing the complexity of the problem; 6 the mere representation of features appearing on paper maps rather than a consideration of what is appropriate for digital map products; and 7 imbalances in the level of detail by which certain features are differentiated as compared to others.

SOME LESSONS LEARNED

A hierarchical arrangement of items, classes, categories, etc., of features and their attributes implies a tree data structure. Further, a requirement to be able to add and subtract attributes and features to any set of them implies list processing. Any numbering or coding scheme of this complexity should obviously be machine computed. Exact codes should be calculated by an algorithm, with the exact numbering system, and the numbers themselves, being of little concern to any user. The concern of the designer should be directed to the task of providing algorithmic consistency and not to the numbers or codes. The task of assigning numbers and working with them, in fact, becomes so onerous that shortcuts are invariably taken by those who go at it that way. For instance, it becomes convenient to assign codes with fixed numbers of digits, with as few digits as possible, and as one number, all to capitalize on the eye's sensitivity to the graphic symmetry of a table, and to reduce clerical exhaustion. This leads to such shortcuts as assigning one digit to identify members of a set when there is reason to believe there will be less than eleven items in the set. When that eleventh element comes along all sorts of games are played to avoid the friction of adding that extra digit. Invariably, attempts are made to fit it in as a member of a previous set, or the members of the previous sets are rearranged, or the code number gets replaced by an alphabetic, or alphanumeric number. This may expand capability to 26 or 36 elements before saturating the code, but all sorts of headaches are created for subsequent software development.

List processing by hand is tedious. Insertion of an item implies retyping the list. Items following the insert have to be renumbered, and these changes are seen to conflict with the need for stability of the code. The initial numbering of items with an extra zero on the lesser significant digit side allows for the insertion of ten items, but only if these ten items arrive in the order they are to be inserted. This is obviously not satisfactory.

All of these things point to the one great pitfall of precipitously becoming involved with assigning numbers or alphanumeric codes to create the system desired, because the problems of manipulating these codes soon consumes all attention and begins to shape the hierarchy or structure that is being constructed. We have the tail wagging the dog. All of these problems are false ones in the context of modern information processing techniques. Regarding efficiencies in the actual coding, we must be concerned with real, and not false efficiencies. Another byte is a small price to pay for just one more advantage, but if it means that to conserve that byte we must scrap a logical system, that effort is utterly pointless.

There may be several valid hierarchies within which a list of items may be organized. If the purpose of a list of cartographic symbol features is purely for the printing of paper maps, a perfectly valid hierarchy could be based on the printing process. Items could be divided by the colour of plate, by intensity screens, by symbol type. On the other hand, a spatial set theory approach on the basis of map space could be utilized to construct a hierarchy that exhausts the total area of the map space. A 'college' would then be included in the group defined by 'designated area: Educational', which would fall in 'built-up area', which would fall in 'land area' (as opposed to 'water area'). Several valid hierarchies could operate in parallel, and that implies that mechanisms to point relations between these hierarchies could be devised, perhaps expressed in the notation of François Bouillé (1978) as a hypergraph-based data structure. Most importantly, it can be seen that complete hierarchies can be built on a single set of criteria. Trouble arises (meaning severe limitations on the usefulness of the result) when classifying criteria are not explicitly and rigorously defined and attempts are made to create hierarchies on mixed criteria.

A number of cartographic features have attributes that are numerical. A contour has a height, a road has a number of lanes, a railway has a gauge, etc. Other measures are less sophisticated, but nevertheless maintain order, e.g., 'Jail complexes: Federal, Provincial, County', ... 'Survey monuments: 1st order, 2nd order, 3rd order, Doppler'. However, most attributes are nominal, e.g., 'Mines: Copper, Gold, Iron, Silver, Uranium'. Because most are nominal there is a temptation to treat everything as nominal, and this can lead to serious and unnecessary losses of information and manipulative capability for those of a higher order. An exaggerated example of unnecessary conversion from higher order to lower order would be to take a thermometer (based on an interval scale of measurement) and assign range nominal values such as FR (frigid), CO (cold), NI (nice), HO (hot), and SW (sweltering), and then to sort these alphabetically: CO-FR-HO-NI-SW. When the order is lost, i.e., conversion from ordinal to nominal, ranging capabilities are eliminated. When the interval value is lost by classifying, other classifications are excluded. When ratios are lost by poor definition of zero, much capability for mathematical manipulation is foregone.

Consideration of ratio and interval numbers as attributes necessitates the use of a 'unit of measure'. An attribute does not only have a 'value', but also a 'value description'. Often a proper 'unit of measure' can answer description questions. 'Contour: 100' becomes 'Contour; fathoms: 100.0'. Formal inclusion of an attribute description, in the manner of a 'unit of measure', applies to nominal attributes as well. 'Factory: Cement blocks', becomes 'Factory; Product: Cement blocks' eliminating ambiguity over to what, exactly, 'Cement blocks' refers. Items may also have multiple attributes utilizing an attribute description, e.g., 'Rail line; tracks: 3; gauge (meters): 1.4351, status: Abandoned'. Attributes can also have multiple values, e.g., 'Hall; Function: community, dance, exhibition'. Multiple attribute and value conventions would eliminate the need for hundreds of special feature codes representing mere combinations, which, when combined with coding restrictions, may lead to the exclusion of important attribute and value combinations. In the proposed Canadian code, for instance, it is not possible to record a 'proposed one-way road' because the other combinations of one-way, elevated, numbers of lanes etc., saturate the digits allocated for features.

CONCLUSIONS

This brief paper has attempted to: 1 provide some definitive ideas on how to solve the problem of adopting a general purpose topographic feature classification system that is inclusive, flexible and open-ended; 2 emphasize the relevance of the map coding problem to those disciplines concerned with the scientific description and explanation of spatial relations; 3 demonstrate that particular aspects of Canada's proposed national classification should be reconsidered; and 4 strengthen the theoretical framework underlying code development.

This research is important because the whole question of standardization in cartography is important. Traditional cartographers have always been concerned with the standardization of map symbols. Standards for digital cartography require new perspectives which will require philosophical approaches to the problem of classification. A cursory examination of the problem reveals that some sort of continuing body such as afforded by national committees of individuals representing a spectrum of map making, map using, and cartographic research disciplines is necessary if some kind of cartographic feature classification system is to find acceptance and be maintained. It is also apparent that the problem is one that requires profound academic and scientific attention at this stage.

ACKNOWLEDGMENT

The authors would like to acknowledge Mossad Allam, François Bouillé, Nicholas Chrisman, Robert Rugg, Lou Sebert, and Ewa Siekierska, who gave up some of their valuable time for interviews and for their ideas.

REFERENCES

ANDERSON, JAMES R. 1961. Toward more effective methods of obtaining land use data in geographic research. *Professional Geographer*, vol. 13, no. 6, pp. 15–18.

ARMAND, D.L. 1965. The logic of geographic classifications and regionalization schemes. *Soviet Geography*,vol. 6, no. 9, pp. 20–38.

BOUILLÉ, FRANÇOIS. 1978. Hypergraphs and cartographic data structures: the HBDS system *ICA 9th International Conference on Cartography*, College Park, Maryland, pp. 1–18.

CANADIAN COUNCIL ON SURVEYING AND MAPPING 1982. Standards for the classification of topographic features. *Draft Report of Technical Committee 1*, Energy, Mines and Resources Canada, Ottawa.

CANADIAN HYDROGRAPHIC SERVICE 1983. *Feature code manual.* Cartographic Research, Fisheries and Oceans Canada, Ottawa.

CLAWSON, MARION and STEWART, CHARLES 1965. *Land use information: a critical survey of U.S. statistics including possibilities for greater uniformity*, (2nd ed., 1969), Resources for the Future Inc., Johns Hopkins Press, Baltimore.

DEFENSE MAPPING AGENCY 1977. *Standard cartographic feature digital identification catalog*, Washington, D.C., Defense Mapping Agency.

DOLBY, R.G.A. 1979. Classification of the sciences: the nineteenth century tradition, Roy F. Ellen and David Reason, eds., *Classifications in their social context*, Academic Press, London, pp. 167–193.

GUTTENBERG, ALBERT E. 1959. A multiple land use classification system. *Journal of the American Institute of Planners*, vol. 25, no. 3, pp. 143–150.

INTER-AGENCY SPATIAL DATA TRANSFER COMMITTEE 1979. *Standard format for the transfer of geocoded information in spatial data polygon files.* Energy, Mines and Resources, Document Code For-SDP-0001, Ottawa.

INTERMINISTERIAL COMMITTEE ON GEOGRAPHICAL REFERENCING 1978. *Proceedings*, Ontario Ministry of Natural Resources, Toronto.

GRIGG, DAVID 1965. The logic of regional systems. *Annals of the Association of American Geographers*, vol. 55, no. 3, pp. 465–491.

LINDERS, JAMES 1978. Geo-referenced data bases. *Proceedings* of the Interministerial Committee on Geographical Referencing, Toronto, Ministry of Natural Resources, pp. 183–214.

ORDNANCE SURVEY, AUTOMATED CARTOGRAPHY UNIT 1980. *Ordnance Survey digital data: feature codes and description.* Appendix D, Digital Mapping Facilities For Customers, Fixed Price Services Section, Ordnance Survey, Romsey Road, Maybush, Southampton.

PECK, A.L. 1965. Introduction, *Aristotle: historia animalium*, (translated by A.L. Peck), vol. 1, Heinemann, London.

REPORT OF THE TASK FORCE ON NATIONAL SURVEYS AND MAPPING 1978, A study conducted for the Department of Energy, Mines and Resources, Surveys and Mapping Branch, Ottawa, Contract No. OSQ77-00013.

SPARKS, ROBERT M. 1958. The case for a uniform land-use classification. *Journal of the American Institute of Planners*, vol. 24, no. 3, pp. 174–178.

STANDARDS ASSOCIATION OF AUSTRALIA 1981. *Interchange of feature coded digital mapping data.* Australian Standard AS 2482-1981, Standards Association of Australia.

U.S. GEOLOGICAL SURVEY TOPOGRAPHIC DIVISION 1980. *Computer files and attribute codes for digital line graphs.* U.S. Geological Survey Topographic Division, Reston, Va.

WITIUK, S.W. 1976. Issues in exchanging spatial systems technology. D.R.F. Taylor, ed., *Current Issues in Geographic Data Processing*, Carleton University, pp. 70–91.

WYNAR, B.S. 1980. *Introduction to cataloging and classification*, 6th edition, Librairies Unlimited, Littleton, Colorado, pp. 400–402.

YAN, JOEL Z., WITIUK, S.W. and FISHER, TERRY 1977. Exchanging spatial systems technology: related issues and a case study, D.H. Douglas, ed., *Applications of Geographic Information Processing*, University of Ottawa, pp. 41–50.

ZARZYCKI, J.M., HARRIS, L.J. and LINDERS, J.G. 1975. Topographic-cartographic data base and automated cartography in Canada. *Proceedings of the Commonwealth Survey Officers Conference*, Ministry of Overseas Development, Paper J 2, pp. 1–9.