SILPOT: A CLUSTER ANALYSIS STUDY OF POTTERY FROM SOUTHERN INDIAN LAKE, MANITOBA

A Thesis

Presented to

The Faculty of Graduate Studies

The University of Manitoba

In Partial Fulfillment

of the Requirement for the Degree

Master of Arts

Department of Anthropology

by

Michael E. Kelly

1978

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MASTER OF ARTS

ABSTRACT

A review of the ceramic classifications now in use for the forest regions of central Canada shows archaeologists have emphasized categorization as the principle on which classes are defined. In this study of a sample of ceramic vessels from Southern Indian Lake, Manitoba, an alternative approach is proposed and implemented. The sample is investigated for taxonomic correlations of attributes in categories of morphological and decorative variation. Difficulties were encountered resulting from incompleteness of vessel reconstruction and analysis distortion caused by logical correlation and almost invariant valuation of some attributes. Cluster analysis procedures applied to the data were successful in recognizing groups in both categories of variation, but except in one instance, the results were not stable, suggesting additional analysis will be required to establish the nature of formal ceramic variation for the Late Prehistoric of the region.

ACKNOWLEDGEMENTS

Many people have directly and indirectly contributed to this thesis. I thank them all. My deep appreciation is directed to my advisor and committee chairman Dr. C. Thomas Shay, who was always available with constructive guidance and inspiration, and to committee members, Drs. William W. Koolage and James B. Nickels for their critical evaluation and support. The project was formulated originally under the guidance of Dr. Charles W. Amsden.

Mr. Oscar L. Mallory, former director of the Churchill Diversion Archaeological Project and the Archaeological Research Center at the University of Winnipeg, and other members of the Center's staff, especially Mr. Gary A. Dickson, contributed willingly their time and knowledge. Mr. Chris Goodwin of Manitoba Hydro was instrumental in securing funds for much of the field work at Southern Indian Lake. Mrs. Joyce Chernichan keypunched the data cards. Mrs. Gail Richards and Miss Karen Dyck typed early working drafts, and Mrs. Richards also lent her talents to drawing many of the figures. The final manuscript was typed by Mrs. Susan Reilly.

And now the question: "Mom, is Dad finished his thesis yet? Mom what's a thesis anyway?" can finally be answered: "It's a book and yes, at last he's really finished!" I dedicate this thesis to my wife, Leslie, and my children, P.B., Kate, and the Boo who lived with it for such a long time.

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CHAPTER I

INTRODUCTION

In all areas of North America where pottery forms a component of the archaeological record it has been the subject of intense study. Brew once said about the American Southwest:

> Largely because potsherds are relatively undestructible... and because they are such sensitive indicators of time and place, pottery has been described and analyzed more than all of the other products of prehistoric Southwestern arts and crafts put together (Brew 1946:245).

For the same reasons expressed by Brew, pottery recoveries from the forest regions of central Canada have been accorded a similar intensity of study which has resulted in a series of ceramic classifications used to ascertain geographical and temporal distributions of prehistoric populations. In more recent years several studies have appeared (Dawson 1973, 1977; Hlady 1970, 1971) which use pottery to distinguish among localized semi-autonomous hunting bands. There has been, as it will be shown in the following chapters, a one-sided approach in devising the ceramic classifications which forms the basis for these studies. As a consequence, archaeologists have a biased understanding of the nature of formal variation in ceramics from these areas.

In this study, an alternative to the conventional approach is described and implemented using a predominantly Late Woodland pottery sample from the Southern Indian Lake Region of northern Manitoba. The main objective is to ascertain if one or more classes of vessels can be found in recognized categories of formal ceramic variation.

Characteristics of vessel morphology and decoration were distinguished and analyzed independently using various methods of cluster analysis. These are multivariate mathematical techniques which generate classifications from measures of similarity among objects in a group. They attempt to operationalize a concept of "natural" classification, which is discussed in detail in Chapter III.

A number of difficulties were encountered in implementing this objective. Some of these resulted from the fact that no vessels were whole, and complete restorations have not been possible. Another source of difficulty arose from a necessity to modify the attribute lists after the data had been compiled. These problems will be elaborated upon in discussion of the analysis results.

In outline of the presentation to follow, Chapter II summarizes the regional environment and archaeology, and Chapter III analyzes the conventional approaches to ceramic classification and discusses an alternative. Details of the sample, data, and analytical methods are given in Chapter IV. Results and discussion of the analyses and the conclusions occupy Chapters V and VI.

CHAPTER II

SOUTHERN INDIAN LAKE: ENVIRONMENT AND ARCHAEOLOGY

The Southern Indian Lake region (Fig. 1) in north central Manitoba encompasses over 7000 km^2 of the Churchill River watershed from Leaf Rapids to Missi Falls and includes both Lake Opachuanau and Southern Indian Lake. Numerous small streams supplement the 4 major tributaries which join the Churchill as it flows to the northeast. Southern Indian and Opachuanau pool in shallow, narrow ice-scoured basins gouged from Precambrian Shield bedrock by Pleistocene glaciers. The mean depth of Southern Indian prior to flooding in 1975 was approximately 9 m and it attained a maximum depth of 37 m (Cleugh, Ayles and Baxter 1974). Opachuanau was slightly shallower. Elevation of the lakes was 254 m above sea level and ranged from 256 m in July to 253 m in February. The combined water area of both lakes was 2000 km^2 and shoreline distance nearly 3700 km. Before flooding there were approximately 1400 islands. Distance by water from Leaf Rapids to the north end of Southern Indian Lake is almost 200 km, and the lake is 25 km at its widest point.

The region has a Humid Microthermal Subarctic climate (Trewartha 1954) which is characterized by long cold winters and short cool summers. Twenty-two years of weather records kept at Brochet, 190 km northeast of Southern Indian Lake, show a mean annual temperature of -5.1^{o}C; January and July monthly means range from -29.0^{o}C to 15.3^{o}C respectively (Beke, Veldhuis and Thie 1923:19-23). Mean annual precipitation is 426mm in a summer dominant pattern. A pollen diagram taken from Lynn Lake 150 km west of Southern Indian Lake (Nichols 1967) suggests that no significant climatic

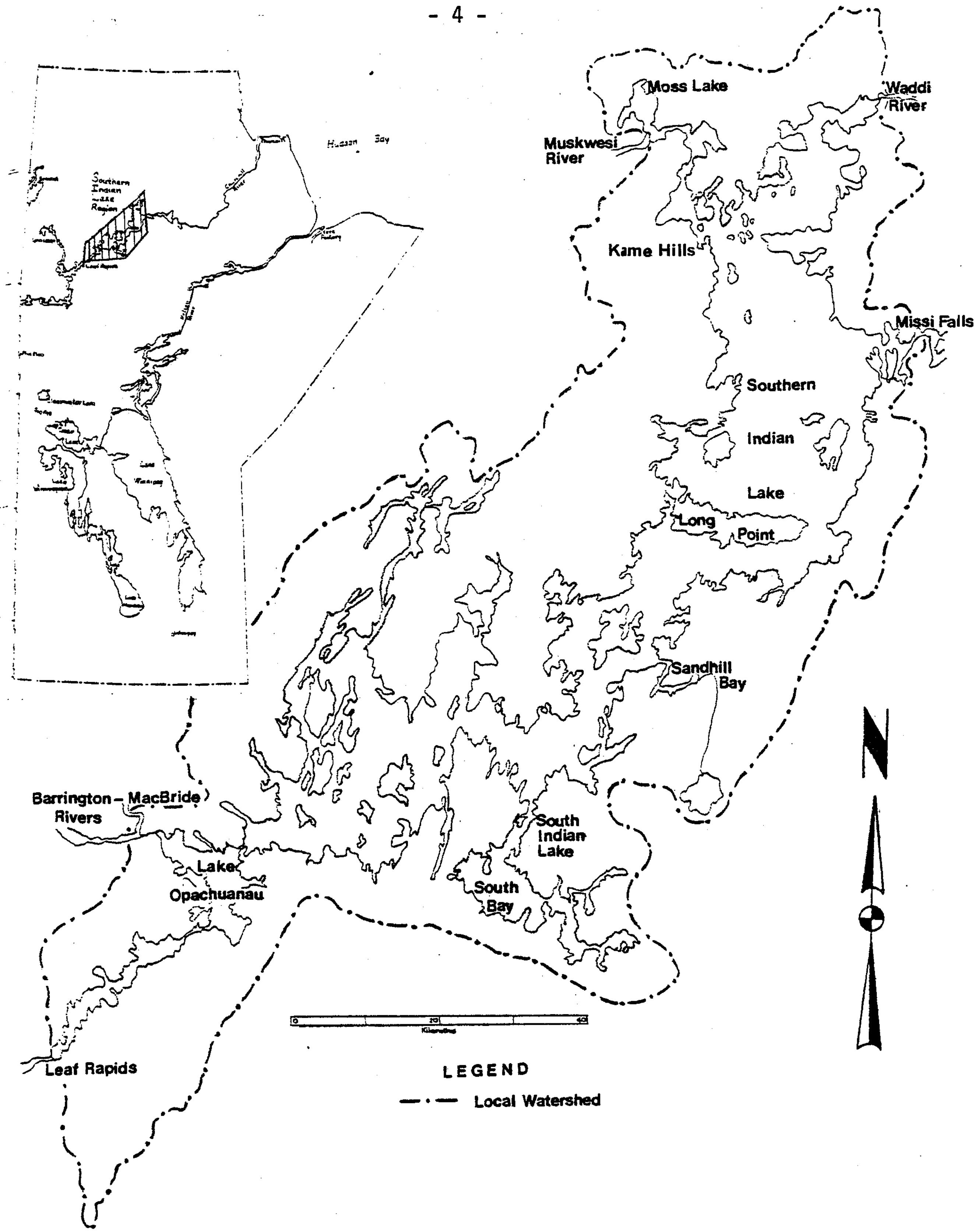

Fig. 1. The Southern Indian Lake Region

change has occurred since deglaciation, although there is evidence of episodic warming and cooling. Winter ice forms in sheltered bays about October 15 and covers the lakes by November 15, although there are a few places where open water leads remain throughout the entire winter (Penner 1974). Break-up starts about May 15 and is complete around June 15.

Geologically the region lies in the Churchill Province of the Canadian Shield (Davies and others 1962). This province is composed of Precambrian metamorphic and metasedimentary rocks. Outcrops consist of undifferentiated series of gneisses, granites, quartz, and related rocks. Quartz appears in the regional archaeological sites as the most common raw material for manufactured lithic tools. The region was covered by continental glaciers during much of the Pleistocene epoch. During the last advance the ice front is believed to have been approximately 300 km south of Southern Indian Lake (Falconer and others 1965). Upon deglaciation, beginning about 8000 years ago, the basin was inundated by a glacial lake (McInnes 1913; Elson 1967:39). Transformation of this lake, recently named Glacial Lake Churchill, into the present-day river basin lakes occurred about 6000 years ago (Ringrose: pers. comm.). Isostatic rebound has continued at decreasing rates since deglaciation and, as a consequence, Southern Indian has undergone changes in pool elevations and alterations of shoreline morphology, which in turn has had an effect on the preservation of archaeological sites in the region (Pettipas 1976:63-65).

The regional landscape is generally low in relief ranging between 250 m and 300 m above sea level (Manitoba Department of Mines, Resources and Environmental Management 1974). It includes Glacio-fluvial features such as eskers and kames, together with calcareous clay till and lacustrine clay deposits. Soil development is slight. Cryic fibrisol, a near permanently frozen mat of decomposing coarse organic material accumulated on bedrock or mineral deposits, is the most widespread soil type. Cryic luvisols and brunisols also occur (Beke, Veldhuis, and Thie 1973:23-32; Clayton and others 1977). Brown (1970, Fig. 1) shows the region to be in the zone of discontinuous permafrost.

Two major forest types are found around Southern Indian Lake (Rowe 1972). In the south is found the Northern Coniferous forest, dominated by closed stands of black spruce. The Northwestern Transition, an open Black Spruce forest, dominates the north. This latter type, which characteristically includes some tundra plant species, represents an ecotone between the boreal forest and the tundra.

Of the 341 vascular plants native to the region (Ritchie 1962) 21 (Table 1) are known to have been used for food by native groups in the Upper Great Lakes (Yarnell 1964). Another 12 (Table 1) had other economic importance. Whether these plants were utilized prehistorically at Southern Indian remains to be fully documented. Hanna's (1975) report of the recovery of pin cherry seeds in a hearth with Late Woodland ceramics at SIL 257 can be considered indicative evidence.

Animal life is abundant but limited in variety. Modern inventories and checklists (Webb 1974, Hecky and Ayles 1974, Wrigley pers. com.) indicate there are some 25 species of ducks, swans, geese and loons, 3 species of grouse, 7 species of mammals, and 10 species of fish (Table 2) which are edible. The relative abundance of these animals can vary not

TABLE 1. Economic plant species of the Southern Indian Lake region; species after Ritchie (1962); use, season, and habitat after Yarnell (1964).

Species Name	Common Name	Use	Season	Habitat
Scripus validus	Great Bulrush	Tubers-starch food Stems-weaving	Autumn & early spring June-July	Shallow protected Littoral
Caltha palustris	Marsh Marigold, Cowslip	Edible greens	Late spring	Damp muskeg
Heracleum maximum	Cow Parsnip Masterwort	Greens & root food	Late spring/ early summer	Lake shore
Populus tremuloides	Quaking Aspen	Sap-syrup Bark/fiber-weaving, matting	Early summer	Upland Successional Forest
Fragaria virginiana	Wild Strawberry	Low food value fruit	Early summer (preservable)	Dry open Uplands
Nymphaea odorata	Pond Lily	Flowers Buds	Summer June - September	Protected Littoral
Maianthemum canadense	Two-Leaved Solomon's Seal	Berries	Summer	Clearings-Open forest
Ribes triste	Red Currant	Berries	July-August	Forest, muskeg
R. hudsonianum	Currant	Berries	July-August	Muskeg, rock slopes
R. oxyacanthoides	Northern Gooseberry	Berries	July-August	Low ground
Rubus pubescens	Dwarf Raspberry	Berries	July-August	Slope & rocky shores

TABLE 1. (continued)

Species Name	Common Name	Use	Season	Habitat
Rubus strigosis	Raspberry	Berries	July-August	Forest fringes Clearings, early fire succession
Prunus pensylvanica	Pin Cherry	Berries	July-August	Dry clearings, burns, openings
Vaccinium oxycoccos	Small Cranberry	Berries	August-winter	Sphagnum muskeg
Gaultheria hispidula	Creeping Snowberry	Berries	August-September	Mossy forest
Arctostaphylos uva-ursi	Bearberry	Berries	July-October	Exposed rock sand clearings
Cornus canadensis	Dwarf Cornel	Berries	August-October	Muskeg
Lathyrus palustris	Marsh Vetchling	Pea seeds	Late summer	Littoral marshes
Viburnum edule	Mooseberry	Berries	August-September	Forest
Empetrum nigrum	Black Crowberry	Berries	July-November	Open rock
Sagittaria cuneata	Arrowhead	Tuber-food Dried for winter	Late Autumn	Protected littoral
Ledum groenlandicum	Labrador Tea	Leaves-Beverage, Dye, medicine	Spring-Autumn	Muskeg

TABLE 1. (continued)

Species Name	Common Name	Use	Season	Habitat
Andromeda glaucophylla	Bog Rosemary	Leaves-beverage	Spring-Autumn	Muskeg
Abies balsamea	Balsalm Fir	Pitch	Early Summer	Well drained slopes
Larix laricina	Larch	Roots-sewing	Summer	Dry Uplands
Pinus banksiana	Jack Pine	Roots-sewing	Summer	Dry sandy uplands
Juniperus communis	Juniper	Bark-matting	Summer	Rocky soil
Typha latifolia	Cattail	Leaves-matting thatch	Summer	Marshes
Hierochloe odorata	Sweet Grass	sewing, weaving	Mid-July-September	Littoral
Salix interior	Sandbar Willow	weaving	Summer	Sandy beaches
Betula papyrifera	Paper Birch	Bark-canoes, containers	June-early July	Stream, lake muskeg borders
Urtica gracilis	Nettle	Fiber-sewing twine	August-September	Damp clearings

TABLE 2 . Utilizable animal species of the Southern Indian Lake region after Webb (1974), Wrigley (pers. comm.), and Ayles and Koshinsky (1974).

Resource Type	Species Name	Common Name	Use	Seasonality	Location
Water	*Gavia immer*	Common Loon	Food from meat and eggs	Summer and Fall; slight increase in density at staging for migration	Any sheltered inlet or shore area; particularly in the north end of South Indian Lake
	Branta canadensis	Canada Goose			
	Anas platyrhynchos	Mallard Duck			
	Anas rubripes	Black Duck			
	Anas acuta	Pintail Duck			
	Anas carolinensis	Green-winged Teal			
	Anas discors	Blue-winged Teal			
	Mareca americana	American Widgeon			
	Spatula clypeata	Shoveler			
	Aythya collaris	Ring-necked Duck			
	Aythya affinis	Lesser Scaup			
	Bucephala clangula	Common Goldeye			
	Bucephala albeola	Buffelhead			
	Melanitta deglandi	White-winged Scoter			
	Melanitta perspicillata	Surf Scoter			
	Mergus merganser	Common Merganser			

TABLE 2 . (continued)

Resource Type	Species Name	Common Name	Use	Seasonality	Location
	Larus argentatus	Herring Gull	Eggs	Summer	Open Lake Islands
	Larus philadelphia	Bonaparte's Gull			
	Sterna hirundo	Common Tern			
Land Birds	*Canachites canadensis*	Spruce Grouse	Meat	Year Round	Any forest area
	Bonasa umbellus	Ruffed Grouse			
	Pedioecetes phasianellus	Sharp-tailed Grouse			
Land Mammals	*Rangifer tarandus*	Barrenground Caribou	Multiple: Food, clothing shelter covers, bone & antler tools	Nov. & early Dec.	Open forests, northwest region
	Alces alces	Moose		Year round	Throughout region (modern densities 0.5/mi^2)
	Euarctos americanus	Black Bear	Food, Clothing		Throughout region
	Lepus americanus	Hare	Food		
	Erethizon dorsatum	Porcupine			Southern range
	Castor canadensis	Beaver	Food and Fur		Throughout region, increased in south

TABLE 2. (continued)

Resource Type	Species Name	Common Name	Use	Seasonality	Location
	Ondatra zibethicus	Muskrat			Throughout region.
Fish	*Stizostedion viterum viterum*	Yellow Walleye	Food	Open water Peak at spawning in early spring	Lake and inlets, shallow streams during spawning
	Stizostedion canadensis	Sauger		Open water Peak densities spring spawn	Open lake
	Percia fluviatilis	Yellow Perch		Open water	Lake
	Esox lucius	Northern Pike			Inlets
	Hidon alosoides	Goldeye			Lake
	Catostomus catostomus	Longnose Sucker			Lake & inlets
	Catostomus commersoni	White Sucker			Lake & inlets
	Lota lota	Burbot			Deep water
	Coregonus clupeaformis	Lake Whitefish		Open water, Peak densities fall spawning	Lake & inlets Peak density north end spawning
	Coregonus artedii	Cisco		Open water	Lake & inlets

only seasonally but also in cycles over a period of years (Feit 1969). Evidence for use of some of these species during the prehistoric period comes from analysis of 3 faunal assemblages (Dickson 1975a:63-66, Hanna 1975:69-96). Species common to the 3 assemblages are caribou, moose, beaver, muskrat and northern pike.

Archaeological research in the last decade (Wright 1968; Dickson 1972, 1975a, 1975b; Hanna 1975; Kelly 1975; Wood 1975) shows a sequence of occupation ranging from the present day to perhaps 5000 B.C. Eight different cultural traditions are recognized for the prehistoric period which ends approximately A.D. 1700. Occupation appears to have been sporadic until the Late Prehistoric which is represented by Clearwater Lake Phase (Hlady 1970, 1971) materials. A few diagnostic artifacts mixed with Clearwater Lake materials in several sites are the main evidence for earlier occupation. Three of the recognized cultural traditions, Laurel, Blackduck and Clearwater Lake contain ceramics. Laurel (Stoltman 1973) has been dated at SIL54 to 1290 ± 150 B.P. (A.D. 660) (Dickson 1976:13).

Almost all of the 177 recorded sites have materials relating to the Clearwater Lake Phase. Sites range from a few waterworn potsherds and lithic tools collected along cobble or sand beaches to *in situ* material culture scatter stretching a thousand meters along the shore, and several hundred meters into the forest interior. On these sites the distribution of cultural materials is not uniform, but usually exhibits clumped patterns. Aside from the pottery most other artifacts are lithic tools and debris. Chipped tools include a variety of triangular and side-notched projectile points, large biface knives, bifacially flaked adzes, uniface end scrapers, wedges, and a variety of utilized flakes. Also observed in some assemblages were granite cobbles with damaged ends suggesting their use as hammers or anvils. A few bone and antler tools including a harpoon or a lance point (Hanna 1975) have also been recovered. Evidence of cordage and netting is provided by the impressions on the ceramics. Hearths which are frequently associated with fire-cracked rock were the only features recorded.

Twelve radiocarbon dates have been obtained from bone and charcoal samples in association with Clearwater Lake materials (Dickson 1976). The earliest of these is 1010 ± 95 B.P. (A.D. 940) and the latest 300 ± 170 B.P. (A.D. 1650) suggesting an occupation span of about 7 centuries. Historical records researched by Wright (1968:20-21) indicate the residents of Southern Indian Lake at the time of first contacts with Anglo-Europeans in the early 1700's were a semi-isolated band of Cree calling themselves *mishinneppe*.

CHAPTER III

CONVENTIONAL CERAMIC CLASSIFICATION AND AN ALTERNATIVE APPROACH

To date Southern Indian Lake ceramics have been assigned to existing classifications (Wright 1968, Wiersum and Riddle 1971; Hanna 1975; Dickson 1972, 1975a). Four wares with associated types and subtypes are commonly recognized. The most frequently occurring of these is Winnipeg Fabric-impressed ware. MacNeish (1958) first recognized this ware in a sample of about 8,500 sherds recovered in surface collections and excavation of 9 sites in southeastern Manitoba. He considered it diagnostic of the Selkirk Focus which was inferred to represent late prehistoric and early historic Western Cree during a period commencing A.D. k350. The ware was characterized by crushed quartz or quartzite tempered pottery with poor paste consistency and laminated vessel walls. Surface finish was "marked by a series of small ovoid impressions, spaced fairly close together" (MacNeish 1958:163) and, frequently, smoothing of the surface after impressioning. Two methods were inferred to produce the impressions:

1. A babiche fabric was laid on a damp pot and pressed by hand.
2. A babiche fabric was wrapped around a paddle used to beat a damp pot.

Flat lips, out-flaring rims, accentuated right-angled necks, and squat sub-conical to globular bodies characterized vessel morphology.

Three types were differentiated within Winnipeg Fabric-impressed Ware: Alexander Fabric-impressed, Sturgeon Falls Fabric-impressed, and

Sturgeon Punctate. Alexander Fabric-impressed was defined as an undecorated type but with all the ware characteristics. Sturgeon Falls Fabric-impressed type exhibited cord-wrapped paddle edge decoration on the lip and upper rim. Decoration of the rim and upper neck with ovoid, crescentic, rectangular, or round punctates in 1 to 3 rows separated Sturgeon Punctate from the other 2 types. MacNeish observed that while all 3 types were found throughout the Late Prehistoric Period in southeastern Manitoba, the 6 components assigned by him to the Selkirk Focus exhibited a trend for Alexander Fabric-impressed to increase in frequency toward the Historic Period and Sturgeon Falls Fabric-impressed to diminish. Sturgeon Punctate exhibited no trend and in fact, MacNeish noted that this type was rare in southeastern Manitoba, but common in northern Manitoba and Saskatchewan. He also noted that Alexander Fabric-impressed appeared occasionally in northern Manitoba.

Hlady (1970:111-112) established an additional type, Clearwater Lake Punctate, within Winnipeg Fabric-impressed ware. At the same time the Grass River Fabric-impressed type was also described but was not included within Winnipeg Fabric-impressed ware (Hlady 1970:118-120). He later elevated this type to ware status (Hlady 1971:28-29). The Clearwater Lake Punctate type was established from the analysis of 2,013 sherds collected from the Clearwater Lake Site (UN-7) near The Pas, Manitoba. Characteristic of the type was a single row of punctates. Except for high incidences of non-flattened and decorated lips and crushed granite temper, the type description coincides with that of Winnipeg Fabric-impressed ware. Hlady (1971:17-18) cited 2 reasons for establishing the type. Sturgeon Punctate was characterized as having 1 to 3 rows of punctation. MacNeish (1958:172-173) illustrated single row Sturgeon Punctate sherds but captioned them "aberrant". The second reason was the apparent restricted geographic distribution of the type. Hlady (1970:121) concluded that the Clearwater Lake Phase, of which the single row punctate pottery is diagnostic, represents a Woodland Cree occupation in northern Manitoba and Saskatchewan dating between A.D. 1200 to 1750.

Grass River Fabric-impressed was established on the basis of a sample of 733 sherds recovered from 4 sites found in the Lower Grass River and Upper Nelson River area of Manitoba (Hlady 1971:28). These ceramics arealso decorated with a single row of punctates near the vessel rim like Clearwater Lake Punctate. The attribute distinguishing Grass River from Winnipeg Fabric-impressed is the treatment of the exterior vessel surface with a ribbed fabric resulting in a distinctive surface texture. Hlady (1970:117-120; 1971:28-29) considered Grass River Fabric-impressed ware/type diagnostic of the Grass River Phase discrete in geographical distribution from the Clearwater Lake Phase and Selkirk Focus. The Grass River Phase, he inferred, represented a movement to and occupation of north central Manitoba by Swampy Cree from A.D. 1500 to 1800.

Hlady extended his classifactory work of Clearwater Lake Fabric-impressed pottery by devising a series of modes based on certain decorative characteristics of the 312 rimsherds from the Clearwater Lake site. He defined the basic mode as:

> ...treated with a fabric-covered paddle on the rim and lip. The lip has then been smoothed although the fabric impressions are not always removed completely. Smoothing of the outer surface of the rim occurs occasionally. The inner surfaces are always smooth (Hlady 1971:8).

The illustration accompanying the description clearly shows that the basic mode is also decorated by a single row of round punctates. He defines 21 additional modes distinguishable by categorical differences in punctate shape, lip and surface treatment, and lip decoration. The motivation to develop this classification was a desire to measure social distance:

> ...many of the modes herein recorded are the marks of nuclear or extended family groups and...sites which contain particular modes could present a seasonal and/or long-time pictures of food-gathering movements (Hlady 1971:16).

Hlady, does not demonstrate how the modes measure social distance and he acknowledged the possibility that the classification scheme maps a sequence of development in decoration:

> One of the facts which has appeared with the analysis of rim and lip modes from the other sites is the fact that the basic mode is represented in only four of twelve sites. It is therefore, possible that Mode 2 is the primary stage from which the others developed (Hlady 1971:1).

A revision of Hlady's classifications has been advanced by Meyer (1975) based on pottery collections from sites in northeastern Saskatchewan. Meyer notes that Grass River Fabric-impressed Ware occurs in Saskatchewan, but in only 1 site was it the exclusive ceramic style recovered. In other sites it co-occurred with Clearwater Lake Punctate. Because of this distribution he concluded there is too much geographical overlap to invoke typological separation, and the ribbed fabric-impressed surface treatment is equal in importance to those more typical of Winnipeg Fabric-impressed ware (fabric or cord-wrapped tool impressing). Meyer further revised Hlady's mode classification according to an analytical system proposed by Stoltman (1973). According to this system modes are considered independent attributes which in combination establish subtypes. Meyer recognized 12 subtypes of Clearwater Lake Punctate in his sample, several of which were identical to modes in the Hlady scheme. Meyer does not completely adhere to Stoltman's method as he does not statistically investigate mode combinations.

Ceramics of 2 other wares, Laurel and Blackduck, also occur in low frequencies at Southern Indian Lake. Analysis of large samples of these wares from other areas has led to defined types and subtypes or modes (Stoltman 1973, Dawson 1973, Carmichael 1977). However, little use of these classes has been made for the Southern Indian material.

More recently, an informal classification of vessel morphology emphasizing shape has been developed for use in assembladge description. The three major forms are jars, bowls, and plates (Dickson 1975a:15). Bowls are distinguished from jars by being semi-circular in cross-section. Jars approach spherical proportions. Plates, in contrast, have extremely shallow profiles and are eliptical in plan view.

The primary objective in establishing most of the ceramic classifications described above is the construction of cultural history. Establishment of types for this purpose has had a long tradition in North American archaeology extending back to the 1930's. The approach tends to combine descriptive similarities with external information as the basis for an appropriate categorization:

> ...two sets of material which are similar in nearly all features, but which are divided by peculiar forms of one feature (shell contrasted with grit tempering, for example) may be separated into two types if there promises to be some historical justification for the procedure (Ford 1938 cited in Willey and Sabloff 1974: 109).

The mode, subtype, and shape classifications although designed to meet other research objectives also follow a pattern of categorical definition. In these cases, however, no recourse is made to external information in order to substantiate utility.

Because the organizing principle underlying these classifications is definition of classes based on categorical distinctions in a few characteristics, they may be considered "arbitrary" classifications (Sokal and Sneath 1973:18027). The results of an arbitrary classification are monothetic classes meaning all members of a class "possess given characteristics" (Doran and Hodson 1975:160). Artificial classifications can lead to useful partitions of objects, but in order to be logically valid an assumption of properties and consequences termed systems of "analyzed entities" (Sokal and Sneath 1973:19-20) must be met. As an example, at a gross level of artifact classification, archaeological remains from a site can be divided into groups, such as lithics and pottery, based on the substances from which each was manufactured. Each of the substances, rock and clay, has distinctly different physical properties, and thus the artifact consequences of these substances are also different. On the other hand, when we investigate classifactory problems like ceramic decoration, there is no apparent system of properties and consequences involved, if the medium of decoration is held constant, which would lead us to establish *prima-facie* groups.

In such cases "natural" classification (Sokal and Sneath 1973: 18-27) offers an alternative to arbitrary categorization. Natural classification assumes only the existence of potential taxonomic correlation of attributes (Jardine and Sibson 1971:26-27). If various values for different attributes "tend to discriminate entities in similar ways the ...attributes are said to be taxonomically correlated" (Jardine and Sibson 1971:27). The result of natural classification is polythetic groupings in which classes "have been defined because their members are similar" (Doran and Hodson 1975:160) and:

> each member will share with each other member a large number of characteristics in common, but no one characteristic has to be possessed by all members, although of course it may be (emphasis theirs) (Doran and Hodson 1975:160).

These differing approaches to the problem of attribute analysis and artifact classification in archaeology have been the subject of heated debate which started with the Ford (1954a, 1954b) - Spaulding (1953, 1954) exchange. As Dunnell (1973:196-197) points out, the force of Ford's position, as quoted above, lies in the fact that classifications produced by an arbitrary approach are useful. Their usefulness, however restricted they may be, accounts for the persistent popularity of the approach. Spaulding's approach, which involved the use of inductive statistics, was capable of eliciting associational patterns in a rigorous fashion. Because, in this case, classes are derived from the data rather than imposed upon them, the natural approach has enjoyed increasingly wide acceptance.

What seems important to recognize is that neither approach is better than the other: they both can be useful in the study of archaeological materials, but they lead to different understandings.

Another aspect of the problem of classification in archaeology has been discussed by Binford (1965). His ideas center on the recognition that different and independent factors influence the process of artifact manufacture. He suggests:

> We should partition our observational fields so that we may emphasize the nature of variability in artifact populations and facilitate the isolation of casually relevant variables. Our categories should be justifiable in terms of possessing common structural or functional properties in the normal operation of cultural systems (Binford 1965:205).

As examples of some of the factors which can affect the manufacturing process of pottery and thus produce different kinds of end products, even when made by the same artisan, there are the use for which the vessel is intended whether cooking, food storage, water storage, or lighting and heating; the sources of clay and temper; the size of the social group a vessel is intended to serve; and the social relationships with others in which the potter participates. For categories of variation in ceramic populations, Binford discusses morphological variation and decorative variation. Morphological variation includes size and shape characteristics of pottery and while these characteristics will be largely determined by the use to which a pot is to be put, say a cooking pot, other factors may also influence these characteristics. A cooking pot functioning in the context of a small nuclear family is likely to be different from one functioning in an extended family in which food is being prepared for a large number of people.

Decoration, because it is a discrete step in pottery manufacture and involves a different set of techniques from those employed to construct a pot, is a distinguishable category of formal variation. As in the case of morphological variation, use and context may influence decorative characteristics: a pot used in religious ritual is likely to be decorated differently from one used for cooking and it has been shown in 1 case that there can be greater similarity in the design elements appearing on different pottery types coming from the same site than appearing on the same type but coming from different sites (Cronin 1962) implying that the decorative techniques of a group of potters living in close association can become conventionalized to the point where their style can be distinguished from other closely related but separate social groups.

While these 2 categories of formal variation are not exhaustive (consider a category of physio-chemical variation for another) they served as a starting point for developing the strategy of analysis initiated by this study. The natural classification approach was also selected, which is operationalized by various methods of cluster analysis (Thomas 1972). Cluster analysis in this study is undertaken independently on 2 sets of formal characteristics obtained from a single sample of ceramic vessels: 1 set measures morphological variation in the sample and the other decorative variation. At this stage, the strategy is exploratory and is aimed simply at attempting to define some regularities in taxonomic correlation of attributes within the 2 analytic dimensions.

CHAPTER IV

SAMPLE, DATA, AND ANALYTICAL PROCEDURES

The sample (SILPOT) from which the numerical data were drawn is a portion of the aggregate of Middle and Late Woodland vessels collected from sites around Southern Indian Lake. SILPOT numbered 105 vessels, or 40% of an inventory of 256 identifiable vessels. The remainder could not be used because some data from each vessel were missing and the analysis package required complete data. All vessels in SILPOT were reconstructions from rim and body sherds that varied considerably in completeness ranging from a single sherd to almost complete vessels.

Data were collected from individual vessels by first isolating reconstructed ones, then sorting on the basis of decoration, size, and provenience the remaining sherds from various site collections into groups representing individual vessels. Some additional reconstruction was undertaken during this procedure. Those vessels for which complete data could be obtained were enumerated (Appendix 1) and measured, while disqualified ones were only counted. In several cases for sites with substantial ceramic recoveries, there was a residue of small rim sherds which were not sortable into recognizable vessels; these were excluded from the inventory count as well as from the sample.

It was apparent from several of the large reconstructions that post-depositional distortion of original shape had occurred. The most striking example was exhibited by a rim reconstruction of a large jar in which the final join to complete the oriface was displaced outward by 2 cm.

Seventy-nine of the vessels in SILPOT had previously been classified by Dickson (1975a), Hanna (1975), Wright (1968), or myself as Winnipeg Fabric-impressed, Grass River, Blackduck, or Laurel ware (Table 3). Winnipeg Fabric-impressed ware accounted for most of the sample. Many of the 26 unclassified vessels probably belong to this ware as well except for 4 miniature vessels that do not fit the standard descriptions. This latter group are small, irregular-shaped vessels with thick uneven walls, and are decorated with irregularly placed pin-sized punctates. They may represent the work of juvenile potters, and it is perhaps a flaw that this kind of variation has gone unnoticed or unaccounted for in most ceramic classifications. In SILPOT, the 4 miniature vessels along with the 5 Laurel and Blackduck ones, because they form a small proportion of the sample, will be considered outliers or deviant data units and one of the means by which the cluster analysis results can be evaluated will be by their action on these 9 vessels.

In terms of conventional morphological assignment which was made by Dickson (1975a) and myself, SILPOT includes 88 jars, 11 plates and 6 bowls. Many plates counted in the inventory were disqualified from SILPOT for lack of data, and as a group are therefore under-represented. Wood and Wasnick (1976:1) estimated that plates account for as much as 40% of the aggregate. One of the miniatures was classed as a plate and the other 3 were classed as bowls.

The joint distribution of vessels in terms of these 2 classifications

(Table 3) shows the nature and extent to which the categories of each classification are crosscut by the others. This will become important during the analysis when each of these categories is singled out.

Three factors influence the geographical distribution of vessels in the sample: site size, intensity of site occupation, and intensity of excavations in different areas. Forty-seven of the vessels, almost half of the sample, come from 4 sites in the Kame Hills Locality at the north end of the Lake (Fig. 1). The rest, except for 1 vessel of unknown site provenience, are from sites located in 3 other localities. Twenty-nine were recovered in the Sandhill Bay - Long Point area, 9 from South Bay and 19 from the Leaf Rapids - Lake Opachuanau area.

Because of the selection biases involved, SILPOT constitutes an availability sample of vessels from the region. It is not a statistically valid random sample, and it follows that strict inferences cannot be made about parent populations as it cannot be assumed that sample variability is representative of population variability. SILPOT is treated here as a population and is investigated for grouping patterns which may represent only a fraction of those in the parent population.

Attribute selection was undertaken with the objective of analysing decorative and morphological variation separately. This required explicit definition and categorization of attributes as discussed in the preceding chapter. Attributes also had to be coded in such a way that they were compatible with the computer analysis package. Thus, following Anderberg's (1973:28) terminology,

TABLE 3. Contingency of conventional decorative and morphological classifications.

Decorative	Morphological			Total
	Jar	Plate	Bowl	
Winnipeg Fabric-impressed	55	10	1	66
Grass River Fabric-impressed	6	0	2	8
Blackduck	4	0	0	4
Laurel	1	0	0	1
Unclassified	22	1	3	26
TOTAL	88	11	6	105

33 binarized nominal attributes (Table 4) were defined to measure decorative variation and 7 continuous ratio variables (Table 5) measured morphological variation. Attribute selection and definition of measurement followed in part McPherron (1967) and Hlady (1970, 1971).

With 1 exception, all of the decorative attributes reflect the presence or absence of purposeful modification of vessels during the final phase of manufacture. These modifications serve no known practical purpose, although they may be useful to the archaeologist in distinguishing social groups or measuring social distance. The exception is the presence or absence of drying cracks (BDCOR5). This attribute was included because it may have value in measuring manufacturing skill.

The variables selected to reflect vessel morphology are less than an ideal character set because they do not measure overall variation, but only variation centered around vessel orifaces. For example, vessel depth could not be estimated in most cases because of incomplete reconstruction. This resulted in a loss of important information, but I decided to proceed in this study with a larger sample without this variable rather than reduce sample size further.

Analysis of the data was accomplished with the computer package CLUSTAN 1c programmed by David Wishart using the University of Manitoba's IBM 370/68 system. CLUSTAN is a multiple procedure program which provides a large number of analysis and result options. Raw data were first transformed into similarity measures among all entities. Squared Euclidean distance (D^2ij) (Appendix 2) was the measure adopted.

TABLE 4. Binary attributes used in measuring vessel decoration.

Attribute Code	Attribute
BDCOR1	Smoothed exterior surface
BDCOR2	Fabric impressed exterior surface
BDCOR3	Rib fabric impressed exterior surface
BDCOR4	Cord wrapped tool impressed exterior surface
BDCOR5	Drying cracks
BDCOR6	1st row exterior punctates
BDCOR7	2nd row exterior punctates
BDCOR8	3rd row exterior punctates
BDCOR9	1st row interior punctates
BDCOR10	2nd row interior punctates
BDCOR11	Lip row punctates
BDCOR12	Irregular punctate placement in row
BDCOR13	Round punctates
BDCOR14	Elongate/tear drop punctates
BDCOR15	Lunate punctates
BDCOR16	Rectangular punctates
BDCOR17	Pronounced bossing
BDCOR18	Slight bossing
BDCOR19	Smoothed lip
BDCOR20	Fabric impressed lip
BDCOR21	Cord impressed lip
BDCOR22	Tool impressed lip (other than punctates)
BDCOR23	Smoothed lip interior
BECOR24	Fabric impressed lip interior
BDCOR25	Tool impressed lip interior
BDCOR26	Pin hole size punctates
BDCOR27	Normal size punctates
BDCOR28	Flat lip
BDCOR29	Rounded lip
BDCOR30	Exterior fillet
BDCOR31	Interior fillet
BDCOR32	Incised line in punctate decorative field
BDCOR33	Cord impressed lip interior

TABLE 5. Continuous variables used in measuring vessel morphology

Variable Code	Variable	Definition and Measurement
XORLENG	Exterior oriface length	Concentric circle or caliper measure to nearest even cm.
XORWIDE	Exterior oriface width	Concentric circle or caliper measure to nearest even cm.
RIMTHICK	Rim wall thickness	Caliper measure of vessel wall 2.5 cm from lip for large vessels and 1.25 cm from lip for small vessel to nearest mm.
LIPTHICK	Lip thickness	Caliper measure distance across lip to nearest mm.
LIPANG	Lip exterior wall angle	Angle measure of angle subtended by lines tangential to the lip and exterior vessel wall to nearest degree.
W/L RATIO	Width-length ratio	XORWIDE divided by XORLENG
L/R RATIO	Lip-Rim wall ratio	LIPTHICK divided by RIMTHICK

There were several reasons for its use. First it was suitable to the problem of assessing similarity among physical objects. Also, it was desired to maintain consistency over the different analysis methods and in manipulation of both the binary and ratio data sets. D^2ij was the only similarity measure available in CLUSTAN which had this capability. Further, its use avoided the problem of treating double-absence scoring in binary data encountered with other similarity measures because only disagreement in scores is considered.

Four different methods of cluster analysis were used: Ward's method (WARD), Iterative Relocation (RELOCATE), Monothetic Hierarchic Division (DIVIDE), and Mode (MODE). Readers are referred to Anderberg (1973), Everitt (1974), and Wishart (1975) among others for detailed descriptions and discussions of these techniques. Ward's method and Iterative Relocation are both hierarchical agglomerative procedures. Analysis with these methods begins with each entity considered as a single cluster and ends with 1 cluster composed of all the entities. Each step of the analysis causes the fusion of the 2 most similar clusters reducing by one the number of clusters for the beginning of the next step. A significant level of classification is indicated by a large change in similarity coefficient between 2 successive classification levels (Wishart 1975:35). The similarity coefficient is the value of D^2ij between the fused clusters in a particular step.

WARD differs from the computational procedure described by Ward (1963), but it retains the methodological limitation of the original. The CLUSTAN algorithm combinatorially transforms a matrix of similarity measures during the fusion process by deleting 1 row and 1 column of the matrix at each fusion of 2 clusters in such a way that the resulting similarity coefficient is twice the value of the coefficient used in Ward's computational procedure, although it produces the same sequence of fusions (Wishart 1975:35-36). The drawback of the method is that misclassifications tend to occur in the significant classifications appearing in the late stages of analysis because "fusions begin where group affinites are weakest" (Clifford and Stephenson 1975:127) in the early stages of analysis and once entities are combined, no recombination is possible.

RELOCATE overcomes this problem by moving entities from cluster to cluster between fusions. The procedure (Wishart 1975:43-48) begins by taking some previous classification such as a Ward's Method partition at the 10 cluster level, or by randomly allocating entities into a number of groups and then testing each entity in turn for reassignment. If higher similarity is measured between the entity and another cluster than exists between the entity and its resident cluster the move is made. Relocation proceeds in cycles through all entities until there are no moves in a cycle. Between cluster similarities are then computed from cluster means and the 2 most similar clusters are fused. At this point a new cycle of entity relocation and cluster fusion starts and repeats until the final fusion of all entities into a single cluster is encountered.

As the name suggests, DIVIDE (Wishart 1975:59-62) approaches the grouping problem from a divisive rather than an agglomerative perspective.

The starting point is a single cluster composed of all entities. This cluster is divided into successively smaller ones at each stage on the presence or absence of binary attributes selected by the algorithm to yield the maximum D^2ij in any possible division of undivided attributes. By maximizing variance between clusters DIVIDE also tends to minimize within cluster variance by increasing the number of characters which are constant valued at each division. Although the analysis could continue until each entity was separated into a unique cluster, in practice the subdividing process is usually stopped at some predetermined level.

Collectively, these 3 procedures just described have a limitation which is prone to give misleading results. Each method attempts to minimize the within-group sum of squares and as such are minimum-variance clustering procedures. The problem of minimum-variance methods of cluster analysis has been reviewed by Wishart (1969:291-295). These methods impose a "constraint on the spread, or variance, of clusters of points" (Wishart 1969:282), and consequently tend to force data into predetermined patterns. Nevertheless, useful information can be obtained, but it must be augmented by complementary analyses.

Mode was proposed by Wishart (1969) as a method which would resolve clusters irrespective of their shape or variance and overcome the problem of "chaining" caused by data scatter. MODE (Wishart 1975:51-56) searches for natural groupings by "estimating disjoint density surfaces in the sample distribution" (Everitt 1974:34). From a matrix of similarity coefficients, an average coefficient value of a selected number of least different entities is computed. Entities are ordered ascendingly by this value, and the entity with the lowest value initiates analysis as the first cluster. Other entities are "introduced" in order and depending on comparative inequalities of different computed coefficients, the entity forms a new cluster, joins an existing cluster, or acts as a link to fuse 2 existing clusters. The unique feature of MODE is that there is always 1 cluster at the beginning and end of the analysis. For some data sets no more than 1 cluster or mode is ever resolved indicating no natural grouping in the data. More typically, a number of modes are resolved by progressive introduction of entities until fusion of clusters begins to occur. The number of modes resolved prior to the first fusion of established clusters represents the maximum number of natural groupings.

CHAPTER V

CLUSTER ANALYSIS RESULTS AND DISCUSSION

Anderberg has observed:

> When cluster analysis is used as a tool of discovery one cannot anticipate what combinations of variables, weights, data units, association measures, and clustering methods will lead to interesting classifications. The first cycle through a clustering problem may give a tentative partition which conflicts in important respects with the analyst's appreciation of the problem and its context. Such results immediately suggest the need to alter the formulation of the problem for another cycle through the clustering method in search of a better fit for the data set (Anderberg 1973:183).

Except in the most unusual circumstance, cluster analysis studies involve the repeated application of methods. For clarity, I have organized the results of this study into 12 analysis "trials", each with an objective, method, and results and discussion section. The first 4 trials pertain to morphological classification and the remaining eight to decoration. The trials are paired for convenience in evaluating results of the minimum-variance procedures WARD, RELOCATE, and DIVIDE with those of the variance-free procedure MODE. In the first pair of trials in each series, analysis was made of the complete data matrices; further analyses were then conducted on selected vessels and attributes of the sample. The rationale behind this strategy was to first investigate the collection as assembled making no assumptions. Subsequent analyses allowed information gained from previous experiments as well as external information to be used in selecting vessel and attribute subsets.

Two methods were used to compare and interpret resultant classifications. The first involved use of contingency tables (Anderberg 1973:205), but due to the problem of low expected frequencies in many cells in these tables, the usual statistical tests of association between partitions were not made. A second method involved contrasting character profiles for various clusters in different classifications (Anderberg 1973:180). For the morphological classifications this amounted to noting the differences in the means and standard deviations of variables among clusters, while in the decorative classifications the ratio of percentage occurrence of an attribute in a cluster to its percentage occurrence in the sample was plotted.

I also devised a relative measure of the degree of similarity attained by various classifications to aid in interpretation. It is termed here the Index of Similarity and is the ratio of the similarity coefficient generated by the minimum-variance procedures at a significant level of classification divided by the maximum obtainable coefficient. Maximum coefficients can be determined or estimated using the computational formulas for D^2ij (Appendix 2). In the case of binary attributes, the maximum coefficient is simply the number of attributes analyzed as this represents the maximum possible number of mismatches. For continuous variables an estimate was calculated from the sample by using the extreme z-scores for each variable in the data matrix. The Index values range from 0.0 to 1.0. A value of 0.0 indicates complete similarity among entities, and a value of 1.0 represents dissimilarity.

Morphological Classification

The frequency histograms and summary statistics for the 7 variables (Figs. 2-8) measuring morphological variability show a tendency for bimodality in oriface width (XORWIDE) and the width-length ration (W/L RATIO). Multimodal tendencies are observable in the distributions of oriface length (XORLENG), lip-exterior wall angle (LIPANG), and the lip-rim wall ratio (L/R RATIO). The lip exterior wall angle (LIPANG) and width-length ratio (W/L RATIO) exhibit strong positive kurtosis. Oriface length (XORLENG) and width (XORWIDE), and the width-length ratio (W/L RATIO) are skewed. Because of the obvious "system of analyzed entities", in this case metric consequences derived from different geometric vessel shapes represented in the sample, it is reasonable to expect that the techniques will classify the plates separate from the rest of the sample.

Trial 1

Objective: To find morphological classes in SILPOT based on minimum-variance procedures.

Method: Subject the data matrix of 7 variables measured for 105 vessels to procedures WARD and RELOCATE. Two RELOCATE analyses are produced by initializing the procedure from different starting partitions:

1. WARD-10: The 10 cluster partition obtained from procedure WARD in this trial.
2. RIP-10: 10 clusters obtained by random assignment of vessels.

Results and Discussion: Printed output for each of the 3 analyses

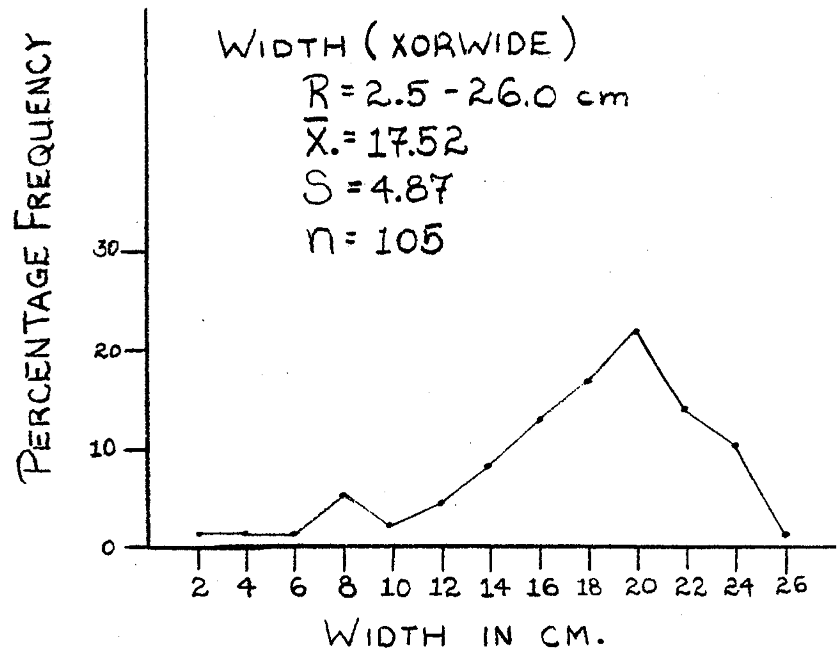

Fig. 2. Percentage frequency distribution for XORWIDE

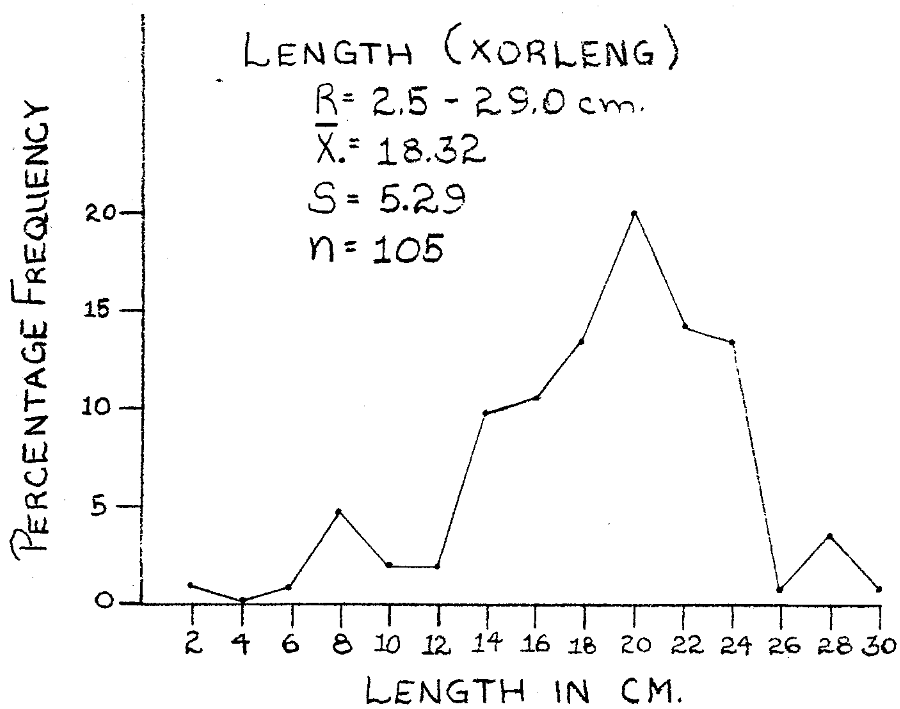

Fig. 3. Percentage frequency distribution for XORLENG

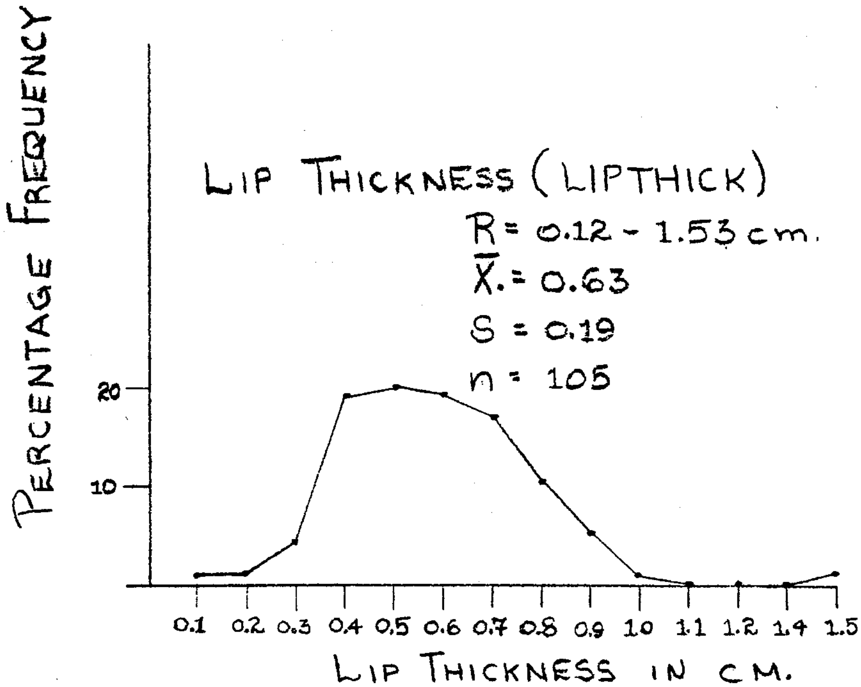

Fig. 4. Percentage frequency distribution for LIPTHICK

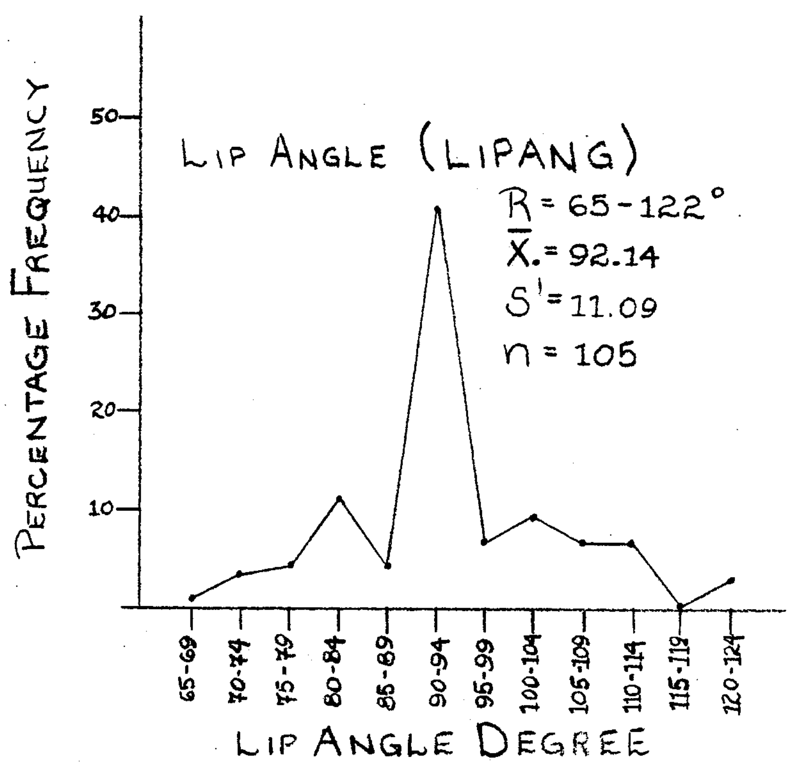

Fig. 5. Percentage frequency distribution for LIPANG

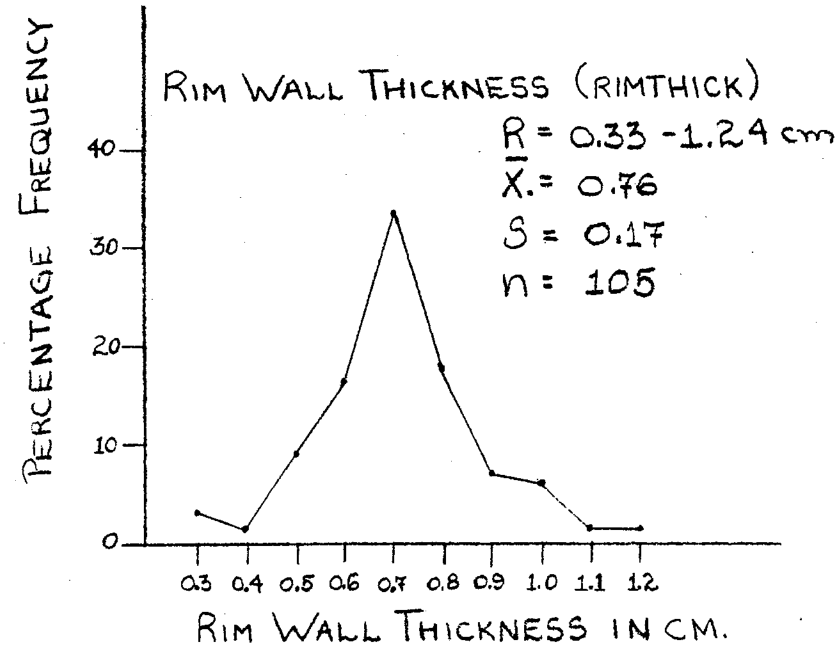

Fig. 6. Percentage frequency distribution for RIMTHICK

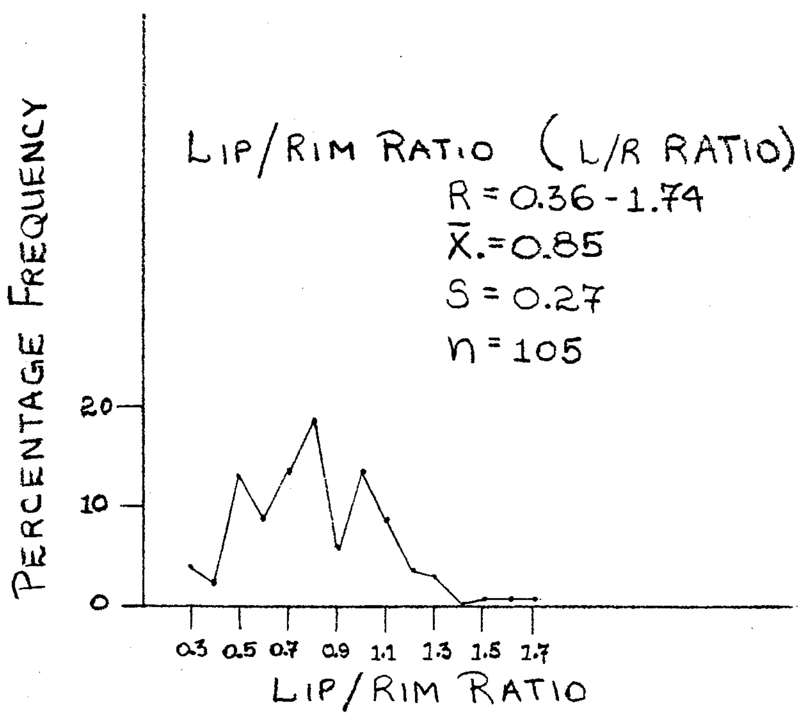

Fig. 7. Percentage frequency distribution for L/R RATIO

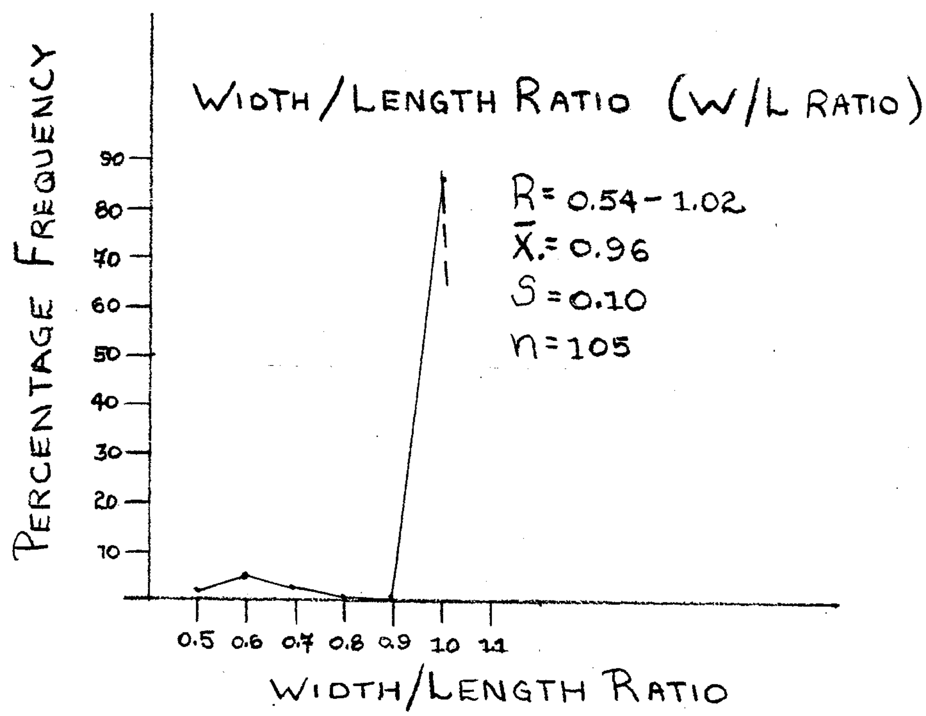

Fig. 8. Percentage frequency distribution for W/L RATIO

consistently indicated a significant classification at the 4-cluster level. This is shown in Fig. 9 as the fusion level which preceeds the marked change of gradient in the similarity coefficient curves. As indicated in the preceeding chapter, the similarity coefficient is the value of D^2ij between 2 clusters which fuse at a particular step, and a significant grouping is indicated by large relative changes in coefficient values. A comparison of the number of vessels in each of the 4 clusters for each analysis (Table 6) reveals the 2 RELOCATE analyses each generates 4 complimentary sized clusters, and although WARD also finds 4 groups, only one of them is equal in size to any of those generated by RELOCATE. A contingency table comparison (Table 7) of the 2 RELOCATE classifications shows complete coincidence in assigning vessels to complementary sized clusters. The difference between the 2 results lies in the arbitrary ordering of the clusters. Using the RELOCATE RIP-10 classifications as the referent for both RELOCATE analyses in the rest of the discussion, a comparison to the WARD classification (Table 8) reveals disagreement in vessel assignment in three of the 4 clusters. They only agree for the clusters with 10 vessels. The mismatches observed in this comparison, as discussed earlier, may result because WARD is incapable of reassigning members to different clusters once they are placed. Consequently the classifications which most reasonably represent an optimal grouping of vessels in this trial are the RELOCATE classifications. Again using the RELOCATE RIP-10 partition as representing this optimum classification, Table 9 lists the means and standard deviations of each variable for vessels in each cluster together with t-values and F-ratios which compare cluster means and variances to sample means and variances, respectively (Appendix 3).

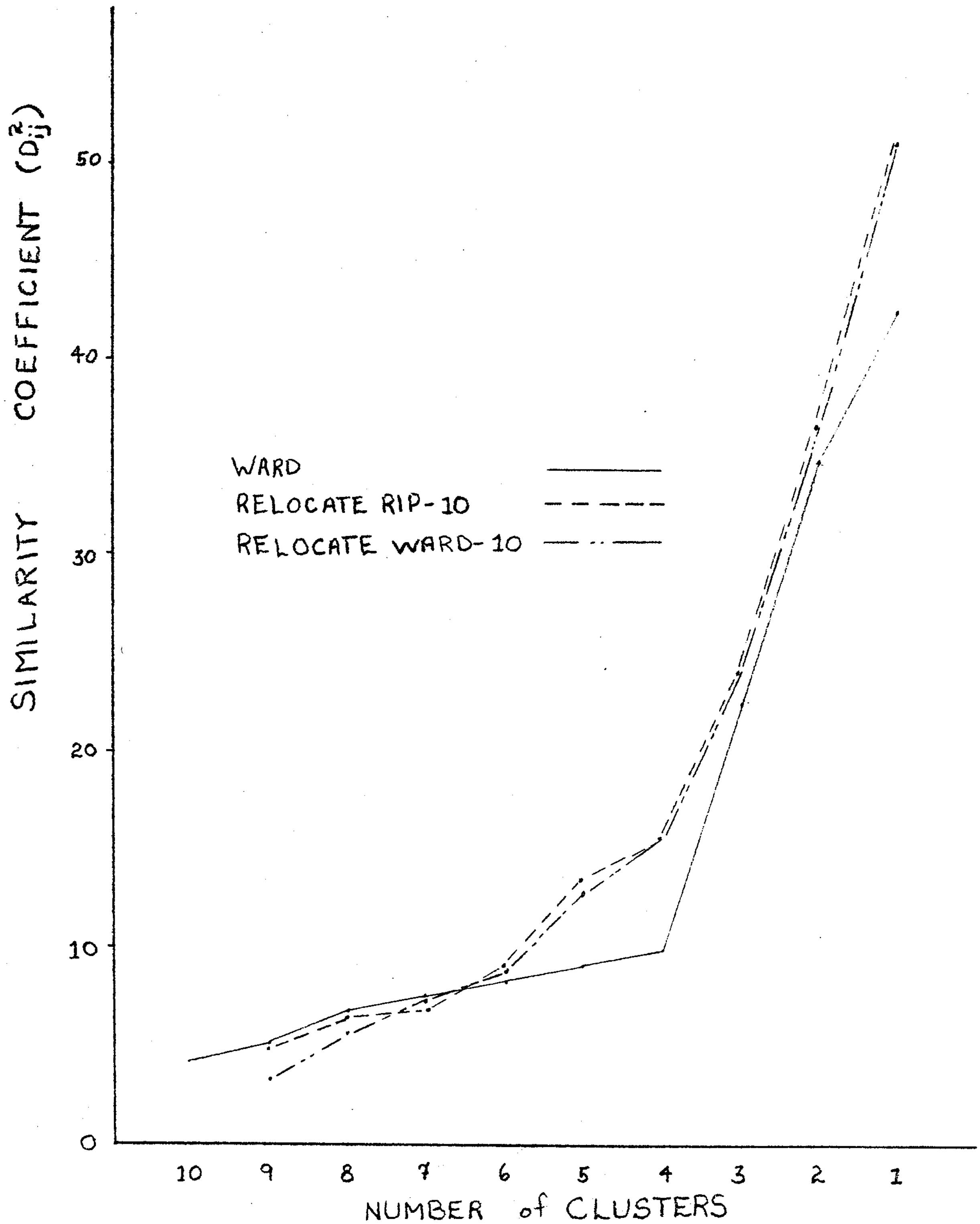

Fig. 9. Similarity coefficient curves for WARD, RELOCATE, WARD-10 and RELOCATE RIP-10 in Trial 1

TABLE 6. Cluster size (n) for analyses in Trial 1.

Procedure	No. of Clusters	Cluster Size (n) 1	2	3	4	Total
WARD	4	30	47	18	10	105
RELOCATE WARD-10	4	39	37	19	10	105
RELOCATE RIP-10	4	39	10	37	19	105

TABLE 7. Trial 1 contingency table comparison between the RELOCATE WARD-10 and RIP-10 classifications.

RELOCATE WARD-10	RELOCATE RIP-10 1	2	3	4	Total
1	39	0	0	0	39
2	0	0	37	0	37
3	0	0	0	19	19
4	0	10	0	0	10
TOTAL	39	10	37	19	105

TABLE 8. Trial 1 contingency table comparison between the WARD and RELOCATE RIP-10 classifications.

WARD	RELOCATE RIP-10 1	2	3	4	Total
1	30	0	0	0	30
2	7	0	37	3	47
3	2	0	0	16	18
4	0	10	0	0	10
TOTAL	39	10	37	19	105

TABLE 9. Descriptive statistics for clusters in the RELOCATE RIP-10 classification of Trial 1.

Cluster	Cluster Size	Variable	$\overline{X}$.	s	t-value	F-Ratio
1	39	XORLENG	20.10	3.08	.336	.339
		XORWIDE	20.00	3.02	.507	.383
		RIMTHICK	0.70	0.13	-.315	.636
		LIPTHICK	0.76	0.18	.721	.892
		LIPANG	85.20	8.87	-.625	.640
		W/L RATIO	0.99	0.26	.305	.069
		L/R RATIO	1.09	0.21	.881	.622
2	10	XORLENG	24.27	4.67	1.123	.777
		XORWIDE	16.51	3.85	-.208	.623
		RIMTHICK	0.91	0.10	.896	.375
		LIPTHICK	0.55	0.09	-.409	.256
		LIPANG	92.70	7.29	.050	.432
		W/L RATIO	0.67	0.07	-2.895	.598
		L/R RATIO	0.60	0.11	-.883	.184
3	37	XORLENG	19.06	2.93	.140	.306
		XORWIDE	19.03	3.01	.309	.383
		RIMTHICK	0.84	0.13	.480	.667
		LIPTHICK	0.61	0.12	-.086	.413
		LIPANG	98.32	10.97	.557	.978
		W/L RATIO	0.99	0.01	.324	.033
		L/R RATIO	0.74	0.16	-.406	.339
4	19	XORLENG	10.08	3.62	-1.555	.469
		XORWIDE	10.04	3.69	-1.534	.572
		RIMTHICK	0.63	0.17	-.760	1.065
		LIPTHICK	0.42	0.11	-1.096	.382
		LIPANG	94.05	8.88	.172	.641
		W/L RATIO	0.99	0.03	.265	.122
		L/R RATIO	0.70	0.25	-.552	.857

> Small F-ratios indicate variables having comparatively low variation within the cluster and are therefore good diagnostics. Large t-values indicate continuous variables having cluster means which are substantially different from the population sample means for those variables (Wishart 1975:72).

Examination of the variable means suggests that Clusters 1 and 3 represent 2 groups of jars. For both of these clusters the W/L RATIO is almost 1.0 indicating a circular shape of vessel orifaces. Oriface diameters tend to be smaller in Cluster 3, although there is considerable overlap between the 2 clusters. In Cluster 1 lips tilt toward the vessel interior, while in Cluster 3 they tilt outward. Vessel lips tend to be thickest in Cluster 1, while vessel walls are thickest in Cluster 3. Correspondingly, the L/R RATIO values indicate expanding rim profiles are characteristic of Cluster 1 vessels, whereas contracting profiles are characteristic of Cluster 3.

Another group of vessels with round orifaces is represented by Cluster 4, but these are much smaller in size than the 2 clusters just described. This is indicated by smaller vessel diameters for which t-values of -1.555 and -1.534 for XORLENG and XORWIDE were obtained respectively, as well as comparative thinness of vessel walls and lips. In other respects this cluster is similar to Cluster 3. This cluster includes the 6 bowls and 1 miniature (unclassified) plate (Table 3) as well as smaller jars.

Cluster 2 appears to represent the plates included in SILPOT. Here, the W/L RATIO is much less than 1.0 and the rim profiles for this vessel type tend to be contracting. A t-value of -2.895 for the W/L RATIO for Cluster 2 emphasizes the shape difference between plates and circular orifaced vessels in SILPOT. Also emphasized in this cluster is a large mean value of XORLENG.

Small F-ratios occur for only the W/L RATIO on Clusters 1, 3 and 4 which indicates less variation in the clusters than measured in the population. This is reasonable in terms of the separation of plates from these clusters as the plates account for most of the variance measured in this ratio.

Trial 2

Objective: To find morphological classes in SILPOT based on a variance-free procedure and compare these results to those of the previous trial.

Method: Submit the same data matrix used in Trial 1 to analysis with MODE.

Results and Discussion: Two classifications were generated during this analysis, one of 3 clusters after the introduction of 16 vessels and another of 2 clusters after introduction of 96 vessels. Cluster sizes for these classifications are 32, 53, and 20 for the former and 95 and 10 for the latter. Interpretation of the 3-cluster classification is problematic because the 10 plates are assigned along with 43 other vessels to the largest of the 3 clusters. In the 2-cluster classification, however, the 10 plates form a single cluster distinct from the others. An optimum classification for this trial appears to be represented by this latter grouping.

Table 10 gives the descriptive statistics for the variables in each of the 2 clusters. The values associated with Cluster 2 are identical with those listed for Cluster 2 of the RELOCATE RIP-10 classification obtained

TABLE 10. Descriptive statistics for clusters in the MODE 2-cluster classification of Trial 2.

Cluster	Cluster Size	Variable	$\overline{X}$.	s	t-value	F-Ratio
1	95	XORLENG	17.69	4.95	-.118	.876
		XORWIDE	17.63	4.96	.002	1.034
		RIMTHICK	.74	.16	-.094	.972
		LIPTHICK	.63	.19	.043	1.058
		LIPANG	92.08	11.41	-.005	1.059
		W/L RATIO	.99	.02	.304	.066
		L/R RATIO	.87	.27	.093	.995
2	10	XORLENG	24.27	4.67	1.123	.777
		XORWIDE	16.51	3.85	-.208	.623
		RIMTHICK	0.91	0.10	.896	.375
		LIPTHICK	0.55	0.09	-.409	.256
		LIPANG	92.70	7.29	.050	.432
		W/L RATIO	0.67	0.07	-2.895	.598
		L/R RATIO	0.60	0.11	-.883	.184

in the previous trial. Because Cluster 1 represents a pooling of Clusters 1, 3, and 4 of the RELOCATE RIP-10 classification the values are different. For MODE Cluster 1, a low value of the F-ratio is observed for W/L RATIO, but an extreme t-value occurs for the same variable. This emphasizes the importance of circular vessel orifaces in this cluster.

The optimum classifications found in the different trials are consistent and supplementary, but they do not resolve the same level of grouping. Thus a robust classification, by definition identical partitions found by the minimum-variance and variance-free procedures, is not indicated. Also, despite the limited number of attributes descriptive of vessel morphology, the results of both trials are compatible with conventional groupings of the same vessels. It is worth emphasizing that the types are defined on distinctly different kinds of observations, one a visual appraisal of geometric form and the other a quantitative measurement. What emerges from the numerical study which is of interest is possible refinements in the conventionally recognized class of jars. This is suggested by separation of jars into Clusters 1 and 3 in the RELOCATE RIP-10 classification. Because of this, the group, consisting of 88 vessels, was subjected to another round of analysis.

Trial 3

Objective: To find morphological classes in the subset of 88 jars in SILPOT based on minimum-variance procedures.

Method: Subject the data matrix of 7 variables measured for 88 vessels classed as jars to procedure RELOCATE RIP-10.

Results and Discussion: This analysis indicated a significant classification of the 88 jars into 4 clusters (Fig. 10). Clusters sizes and descriptive statistics of the members of each clusters are listed in Tablě 11.

Clusters 1 and 2 represent large orifaced vessels. The distinctions between the two are differences in thickness of lips and rim walls and in the shape of the rim profiles. These were also characteristics which distinguished Clusters 1 and 3 in the RELOCATE RIP-10 classification described in Trial 1. Cluster 3 in this classification is a group of smaller orifaced vessels. Like Cluster 2, the rim profiles tend to be contracting. Cluster 4 is an outlier group which is distinguished from the rest of the sample by non-circular oriface shapes. The t-value and F-ratio attain high diagnostic values for W/L RATIO in this cluster. These 2 vessels appear to be products of post-depositional and reconstruction distortion; one of them is the rim reconstruction mentioned before (Chapter IV) with the 2 cm displacement and the other is a nearly complete vessel reconstruction for which there were measurable differences between the length and width of its oriface.

Trial 4

Objective: To find morphological classes for the subset of 88 jars based on a variance-free procedure and compare the results to that of the previous trial.

Method: Subject the same data matrix used in Trial 3 to procedure MODE.

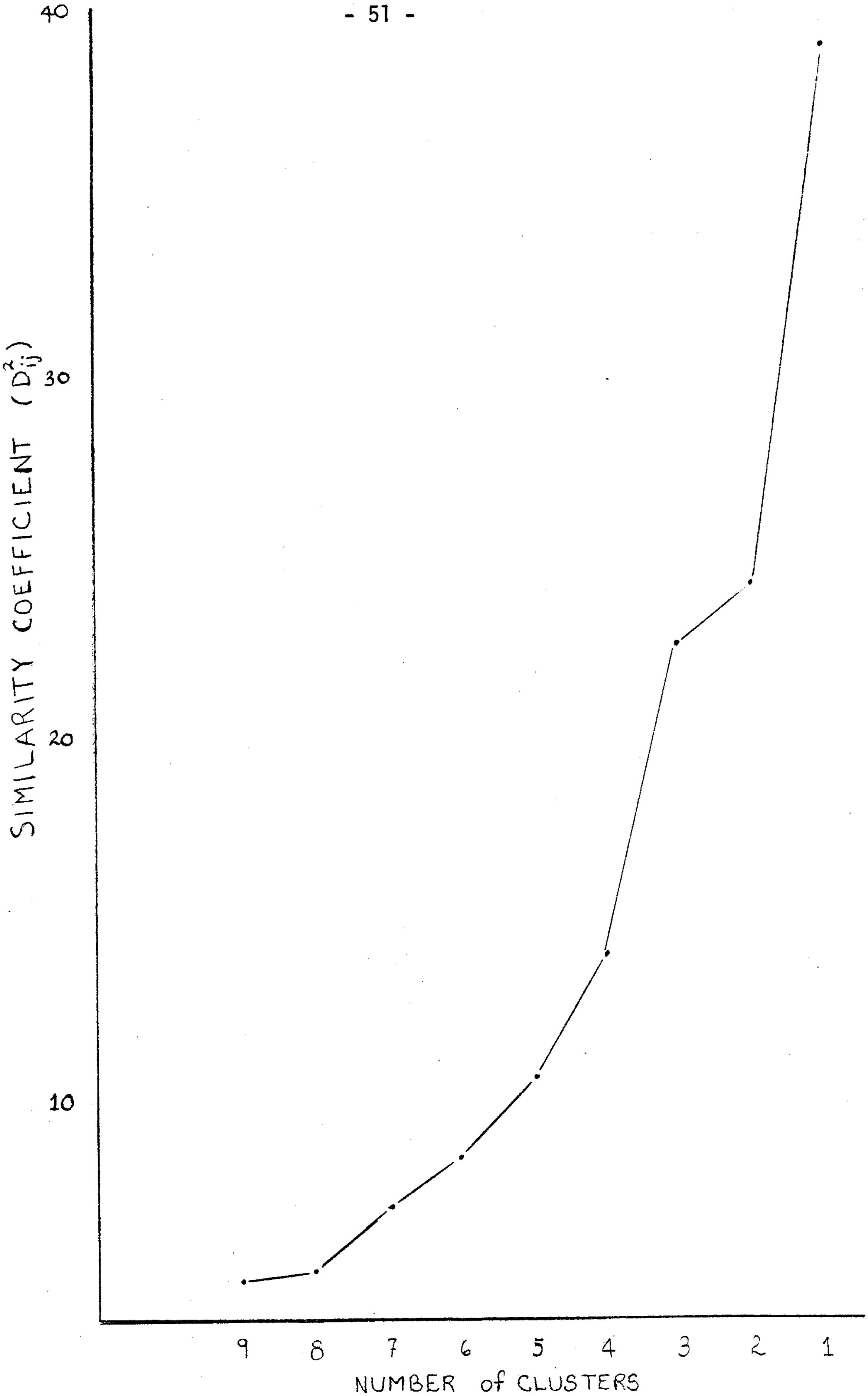

Fig. 10. Similarity coefficient curve for RELOCATE RIP-10 in Trial 3

TABLE 11. Descriptive statistics for clusters in the RELOCATE RIP-10 classification of 88 jars in Trial 3.

Cluster	Cluster Size	Variable	$\overline{X}$.	s	t-Value	F-Ratio
1	25	XORLENG	20.68	2.27	0.535	0.301
		XORWIDE	20.68	2.27	0.551	0.303
		RIMTHICK	0.71	0.14	-0.228	0.756
		LIPTHICK	0.84	0.16	1.018	0.853
		LIPANG	88.12	9.39	-0.304	0.705
		W/L RATIO	1.00	0.00	0.137	0.000
		L/R RATIO	1.19	0.18	1.099	0.517
2	34	XORLENG	20.52	2.51	0.499	0.367
		XORWIDE	20.54	2.50	0.517	0.367
		RIMTHICK	0.83	0.14	0.450	0.791
		LIPTHICK	0.60	0.10	-0.304	0.371
		LIPANG	95.05	12.49	0.316	1.247
		W/L RATIO	1.00	0.00	0.166	0.027
		L/R RATIO	0.74	0.14	-0.606	0.314
3	27	XORLENG	13.77	3.05	-1.129	0.544
		XORWIDE	13.77	3.05	-1.119	0.548
		RIMTHICK	0.68	0.16	-0.408	0.979
		LIPTHICK	0.56	0.14	-0.548	0.608
		LIPANG	90.11	8.92	-0.126	0.636
		W/L RATIO	1.00	0.00	0.137	0.000
		L/R RATIO	0.85	0.21	-0.214	0.676
4	2	XORLENG	18.75	5.25	0.069	1.603
		XORWIDE	16.00	4.00	-0.581	0.937
		RIMTHICK	0.87	0.16	0.720	0.989
		LIPTHICK	0.63	0.07	-0.158	0.173
		LIPANG	93.00	17.00	0.132	2.307
		W/L RATIO	0.86	0.28	-6.389	1.728
		L/R RATIO	0.76	0.23	-0.530	0.778

Results and Discussion: MODE generated classifications first at a 2-cluster level and second at a 3-cluster level. These classifications were generated after the introduction of 16 and 25 vessels respectively. Cluster sizes for the 3-cluster classification are 71, 13, and 4. The descriptive statistics for each cluster (Table 12) shows groups which are arbitrarily arranged as a series of progressively larger orifaced jars. Cluster 2 is further distinguished from Cluster 1 by differences in the angle of lip slope. The L/R RATIO is less than 1.0 for all 3 clusters, indicating the shape of the rim profile is unimportant in cluster formation; however, mean thicknesses of the lips and rim walls do vary among the clusters.

Contingency table comparison between this classification and the one from the preceeding trial (Table 13) confirms there is little agreement between them in terms of joint assignment, and there is no consistent basis for grouping. Dominance in the MODE classification by a cluster to which 81% of the sample is assigned suggests that there is considerable uniformity among the jars. Nevertheless, both analyses reveal a degree of subgrouping not conventionally recognized. It will be recalled from Table 3, there is some stylistic variation in this sample subset introduced by the presence of 5 Blackduck and Laurel vessels. None of these vessels is singled out by either analysis as being deviant from the population by placement in discrete clusters. The statistics, therefore, describe clusters within the population of jars for SILPOT, but these clusters are crosscut by stylistic variation.

TABLE 12. Descriptive statistics for clusters in the MODE classification of 88 jars in Trial 4.

Cluster	Cluster Size	Variable	$\overline{X}$.	s	t-value	F-Ratio
1	71	XORLENG	17.66	4.10	-0.190	0.982
		XORWIDE	17.59	4.07	-0.194	0.972
		RIMTHICK	0.74	0.17	-0.046	1.072
		LIPTHICK	0.67	0.18	0.076	1.077
		LIPANG	89.36	9.50	-0.192	0.721
		W/L RATIO	0.99	0.02	-0.032	1.233
		L/R RATIO	.93	0.27	0.115	1.082
2	13	XORLENG	21.23	2.29	0.668	0.305
		XORWIDE	21.23	2.29	0.684	0.308
		RIMTHICK	0.81	0.14	0.360	0.711
		LIPTHICK	0.61	0.14	-0.250	0.646
		LIPANG	106.38	7.30	1.328	0.425
		W/L RATIO	1.00	0.00	0.137	0.000
		L/R RATIO	0.77	0.17	-0.512	0.461
3	4	XORLENG	23.50	0.50	1.215	0.014
		XORWIDE	23.50	0.50	1.234	0.014
		RIMTHICK	0.69	0.04	-0.349	0.069
		LIPTHICK	0.56	0.07	-0.533	0.189
		LIPANG	81.50	8.76	-0.895	0.612
		W/L RATIO	1.00	0.00	0.137	0.000
		L/R RATIO	0.80	0.06	-0.374	0.062

TABLE 13. Contingency table comparison between the RELOCATE RIP-10 classification of Trial 3 and the MODE classification of Trial 4.

RELOCATE RIP-10	MODE 1	MODE 2	MODE 3	Total
1	24	1	0	25
2	18	12	4	34
3	27	0	0	27
4	2	0	0	2
TOTAL	71	13	4	88

To summarize these 4 trials (Table 14), results of the optimum classifications for the 2 data sets and the Indicies of Similarity derived from the minimum-variance procedures are listed. It will be noted that the Index of Similarity for the analyses involving the total sample is greater than of the jars alone. However, both indices are nearly 0.0 indicating that there is a strong degree of similarity among the vessels. In SILPOT, a large number of vessels are similar in size even though shapes vary. This may account in part for low values of the indices. The only consistent distinction in morphology is that between the plates and all other vessels. While there are other detectable groupings, factors such as overall similarity indicated low Index of Similarity values and placement of the majority of jars into a single cluster in Trial 4; crosscutting stylistic variability and, most important, the limited formal variation measured by the 7 variables leads to the conclusion that these clusters should be considered only hypotheses of morphological classes.

Decorative Classification

Turning to the 8 trials of decorative variation measured by the 33 binary attributes, it cannot be anticipated what patterns will emerge. There is no reason the numerical methods should yield the same results as the categorizing approaches which have been applied by others in the past. Overall variation in individual attribute values expressed as percentage occurrence in the sample (Fig. 11) is considerable. From this graph, it can also be seen there are 8 attributes that are either very high or very low in frequency occurrence.

TABLE 14. Summary of cluster analysis results of morphological variation.

Trial	Procedure	No. of Vessels	No. of Variables	No. of Clusters	Cluster Size 1 2 3 4	Similarity Coef.	Max Coef.	Index of Similarity
1	RELOCATE (RIP-10)	105	7	4	39, 10, 37, 19	15.73	230.29	.068
2	MODE	105	7	2	95, 10	--	--	--
3	RELOCATE (RIP-10)	88	7	4	34, 2, 25, 27	14.09	249.92	.0564
4	MODE	88	7	3	71, 13, 4	--	--	--

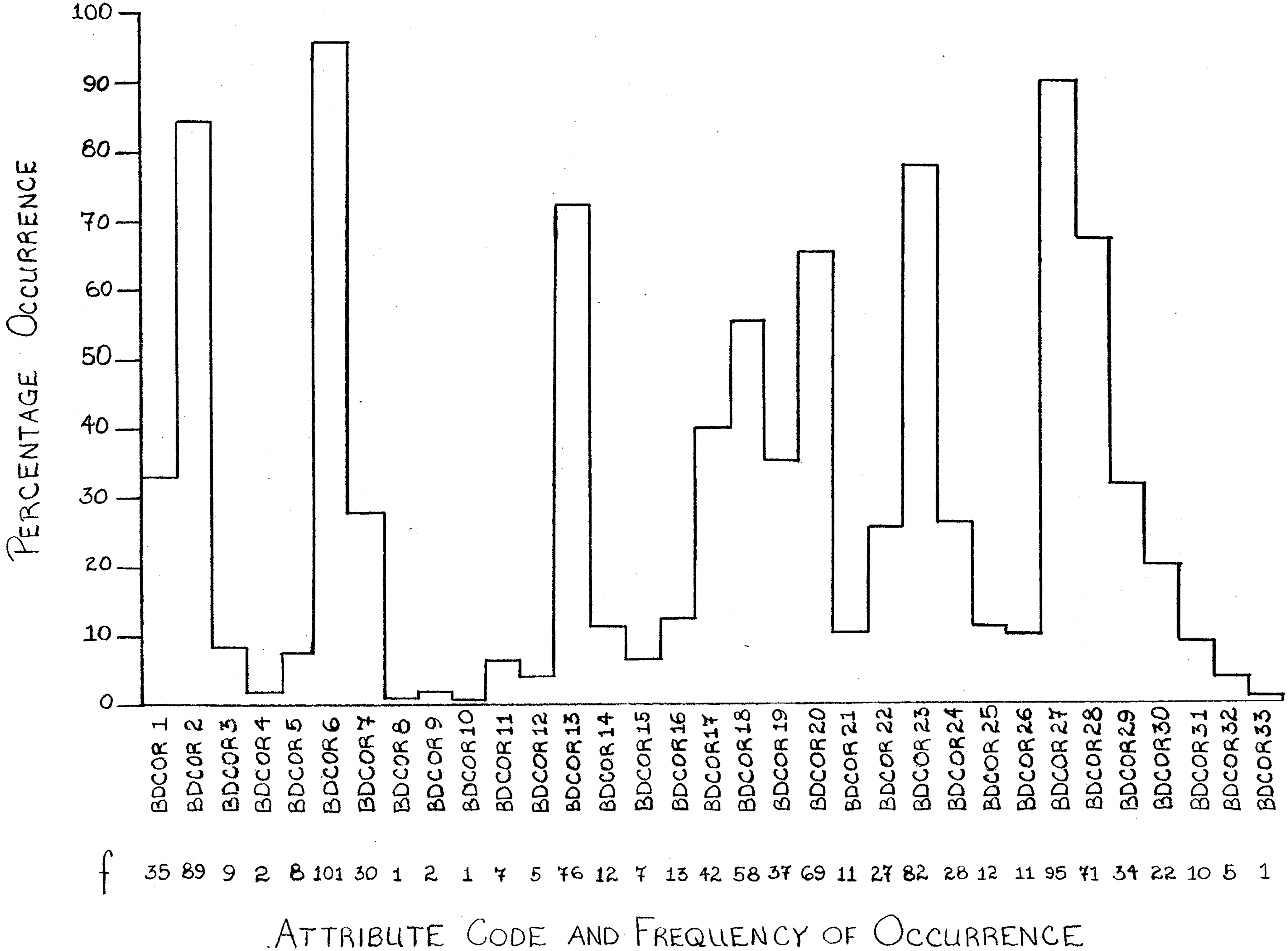

Fig. 11. Percentage occurrence distribution for binary attributes.

First row punctates (BDCOR6) occurs on 96% of the vessels and the 7 attributes listed in Table 15 occur with less than 5% frequency. While these attributes are not invariant (universally present or absent) and thus inadmissable at the outset (Sokal and Sneath 1973:105), they may cause distortions in the analyses as will be seen below. Therefore, the first trials will be interpreted from this point of view.

Trial 5

Objective: To evaluate the attribute list based on the results from application of various minimum-variance procedures.

Method: Analyze the 33 binary attribute data matrix for SILPOT using WARD, DIVIDE and RELOCATE. The latter procedure is initialized from 2 different starting partitions:

1. WARD-10: The 10 cluster classification obtained from procedure WARD in this trial.

2. RIP-10: 10 groups obtained by a random allocation of vessels.

Results and Discussion: Among the classifications generated by WARD the 3-cluster partition was indicated to be of some taxonomic interest with a change in similarity coefficient value of 1.08 at the fusion of 3 clusters into 2 (Fig. 12). Cluster sizes for this classification were 54, 36 and 15 vessels. Significant classifications were found at 2 different fusion levels in the applications of RELOCATE. The RELOCATE WARD-10 analysis shows a marked coefficient change of 0.43 at the fusion of 4 clusters to 3 (Fig. 12) and the RELOCATE RIP-10 change from 5 to 4 clusters was 0.42. Cluster sizes for RELOCATE WARD-10 were 40, 26, 14, and 25; and for the RELOCATE RIP-10 classification they were 14, 17, 22, 25 and 27. A contingency

TABLE 15. Near universally absent ($\leq$5% occurrence) decorative attributes.

Attribute Name	% Occurrence	Attribute
BDCOR4	2.0	Cord wrapped tool
BDCOR8	1.0	3rd row exterior punctates
BDCOR9	2.0	1st row interior punctates
BDCOR10	1.0	2nd row interior punctates
BDCOR12	4.8	Irregular punctate placement
BDCOR32	4.8	Incised line in punctate decorative field
BDCOR33	1.0	Cord impressed lip interior

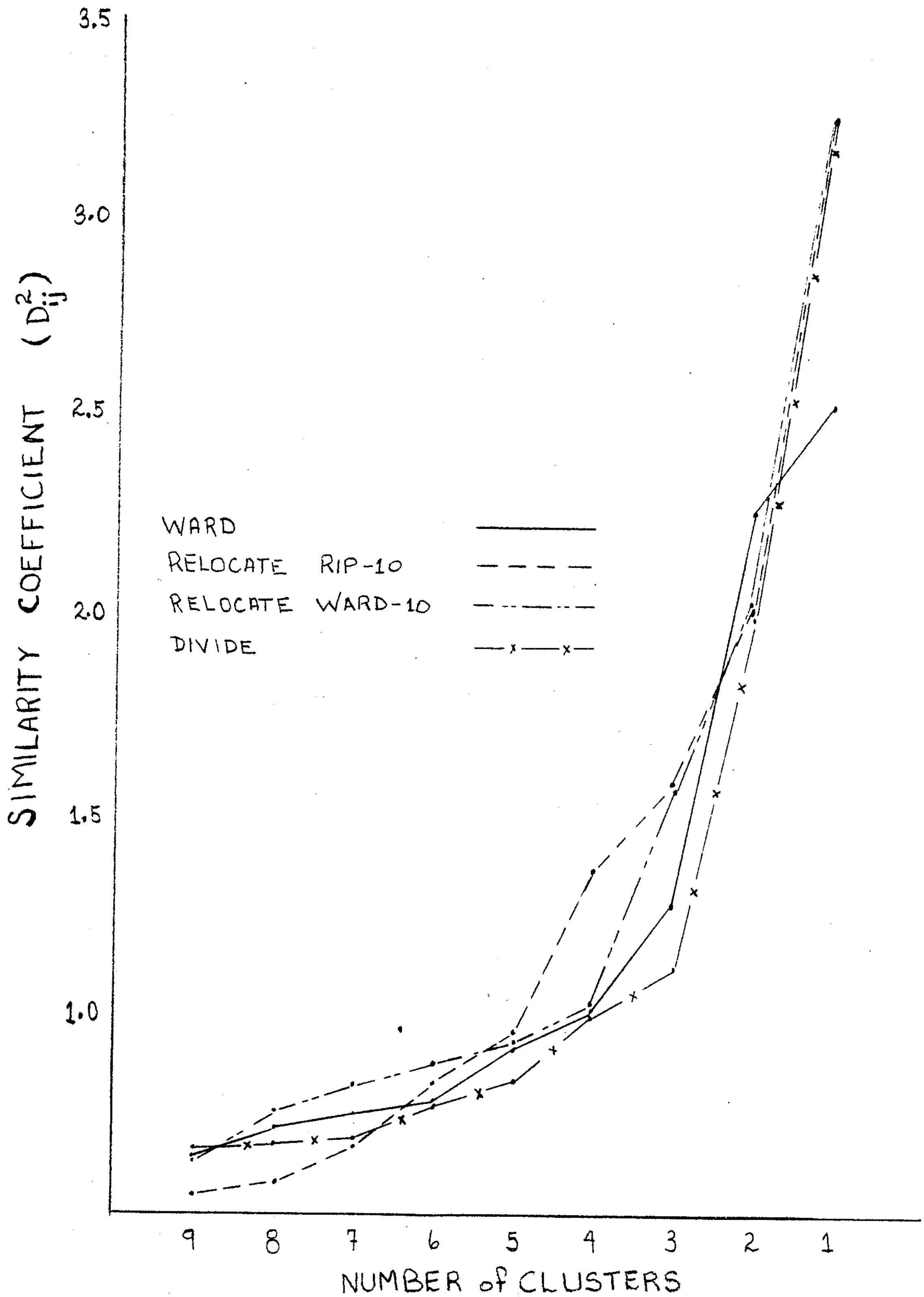

Fig. 12. Similarity coefficient curves for WARD, RELOCATE WARD-10, RELOCATE RIP-10 and DIVIDE in Trial 5

table comparison (Table 16) of these last 2 classifications shows two of the clusters in the RELOCATE WARD-10 partition (Clusters 1 and 4) are identical in membership with 2 clusters in the RELOCATE RIP-10 partition (Clusters 4 and 5). The difference between the 2 classifications lies in the allocation of the vessels of Cluster 3 in the RELOCATE RIP-10 partition. This cluster is divided between Clusters 2 and 5 to form Cluster 1 of the RELOCATE WARD-10 classification. The rest of the vessels in each of these 2 groups formed separate and distinct clusters in the RIP-10 classification. These observations suggest the 2 classifications are hierarchally related to each other.

A comparison of the RELOCATE WARD-10 4-cluster classification to the WARD 3-cluster classification (Table 17) shows there is less overlap in vessel allocation among clusters than in the previous comparison.

Results from DIVIDE provided additional insight into the above analyses. The division of 2 cluster into 3 decreased the similarity coefficient by 0.92 (Fig. 12) signifying the 3-cluster classification is of relative importance. Cluster sizes for this classification were 27, 34, and 44. Comparison of this classification with the RELOCATE WARD-10 4-cluster classification (Table 18) shows the same pattern of allocating vessels from a single cluster as described above in the comparison of the 2 RELOCATE analyses.

In the dendrogram (Fig. 13) accompanying the analysis the first 25 divisions are shown. The first 3 divisions are the most marked, and below this further division appears to occur uniformly in the 3 major clusters with only slight changes registered in the similarity coefficients. Shown

TABLE 16. Contingency table comparison between the RELOCATE WARD-10 and RELOCATE RIP-10 classifications of Trial 5.

RELOCATE WARD-10	RELOCATE RIP-10 1	2	3	4	5	Total
1	0	0	13	0	27	40
2	0	17	9	0	0	26
3	14	0	0	0	0	14
4	0	0	0	25	0	25
TOTAL	14	17	22	25	27	105

TABLE 17. Contingency table comparison between the WARD and RELOCATE WARD-10 classifications of Trial 5.

WARD	RELOCATE WARD-10 1	2	3	4	Total
1	39	4	1	10	54
2	1	22	0	13	36
3	0	0	13	2	15
TOTAL	40	26	14	25	105

TABLE 18. Contingency table comparison between the RELOCATE WARD-10 and DIVIDE classifications of Trial 5.

RELOCATE WARD-10	DIVIDE 1	2	3	Total
1	0	0	40	40
2	26	0	0	26
3	1	9	4	14
4	0	25	0	25
TOTAL	27	34	44	105

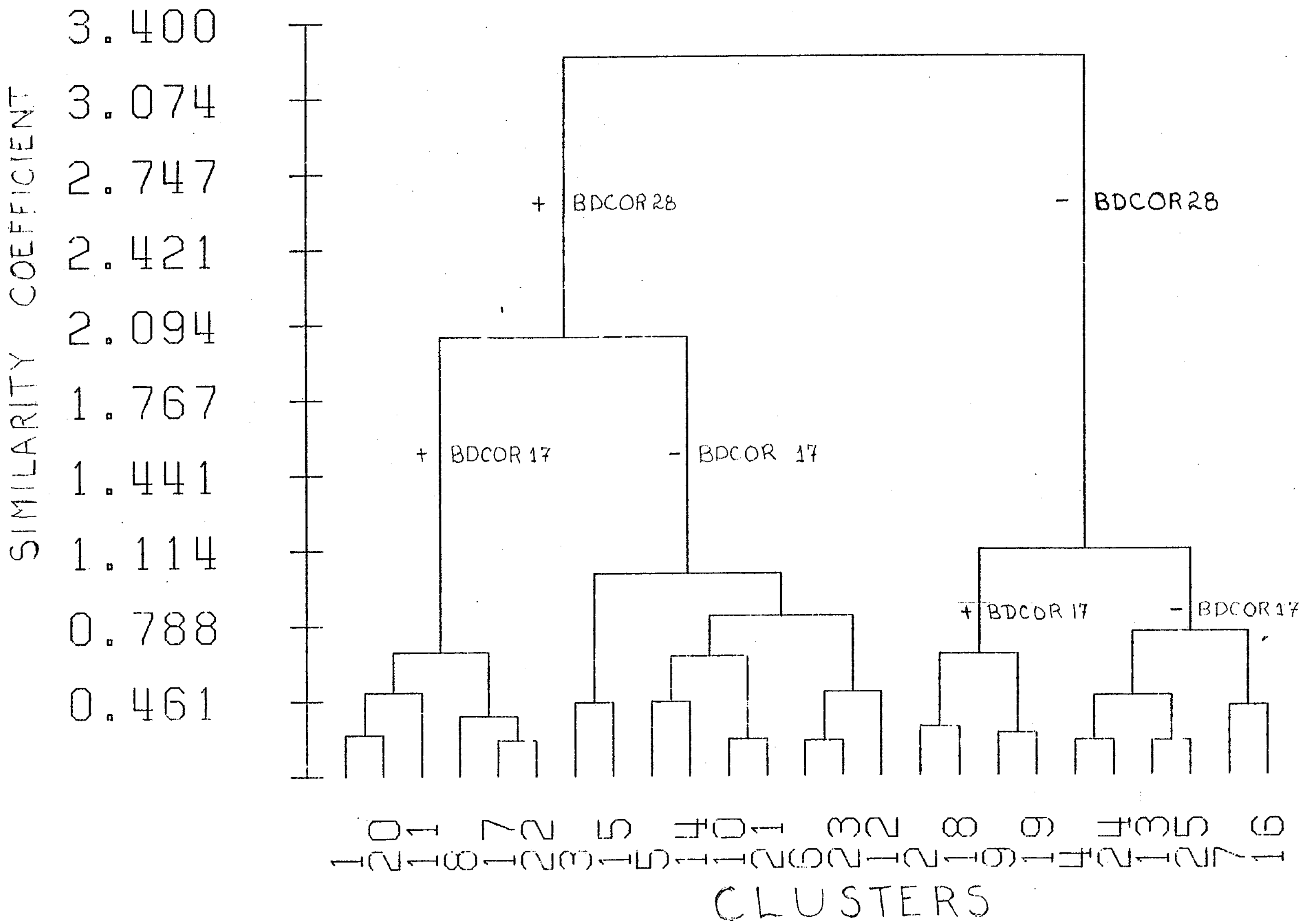

Fig. 13. Dendrogram for DIVIDE in Trial 5.

with the branches in the dendrogram are the values (presence = +, absence = -) for the first 3 divisions. Only 2 attributes are involved: pronounced bossing (BDCOR17) and flat lips (BDCOR28).

Comparisons of DIVIDE and the 2 RELOCATE analyses show the solutions are similar although they occur at different fusion levels. This makes it difficult to pinpoint an optimum classification from among the 3 possibilities. Only 2 of the 33 attributes seem to account for the grouping patterns recognized by these analyses. These results will be further evaluated below following the MODE analysis of Trial 6.

Trial 6

Objective: To evaluate the SILPOT binary data matrix using a variance-free cluster analysis procedure.

Method: Subject the same data matrix analysed in Trial 5 to procedure MODE.

Results and Discussion: MODE did not resolve significant clustering and did not generate a classification. In several instances introduced vessels became minor modes, but they never grew in size sufficiently to satisfy the requisite number of dense points required to qualify the mode as a legitimate cluster (Wishart 1975:53-54). These minor modes rapidly fused into the dominant mode as the analysis progressed. The implication of this analysis is complete uniformity in decoration, in that all vessels are assigned to a single cluster.

The results of Trials 5 and 6 are clearly different. This led me to further explore the minimum-variance procedure results. I chose the DIVIDE 3-cluster classification and listed the percentage occurrence of each attribute for each cluster (Appendix 3). Four attributes, rather than two, account for the definition of clusters. Each of the key attributes, pronounced bossing (BDCOR17) and flat lips (BDCOR28), shows a complementary inverse relationship respectively with slight bossing (BDCOR18) and rounded lips (BDCOR29) (Fig. 14). The attribute list thus includes 2 sets of logically correlated attributes (Jardine and Sibson 1971:25-26; Sokal and Sneath 1973:103-104) which has caused, through redundancy of measurement, double weighting of certain characters. The presence of either one implies the absence of the other, and so to include both distorts the analysis. Correction of the problem for the next trials involved deleting 1 member from each pair thereby removing redundancy and equalizing attribute weights. The attributes deleted were slight bossing (BDCOR18) and rounded lips (BDCOR29). These attributes are in addition to those which were previously noted as almost invariant, and thus another cycle of analysis was necessary to evaluate the attribute list for distortion arising from that source.

Trial 7

Objective: To evaluate the reduced attribute list based on the results from application of various minimum-variance procedures.

Method: Analyze the data matrix for 105 vessels measured on 31 binary attributes with procedures RELOCATE RIP-10 and DIVIDE.

Results and Discussion: No optimum level of classification was found

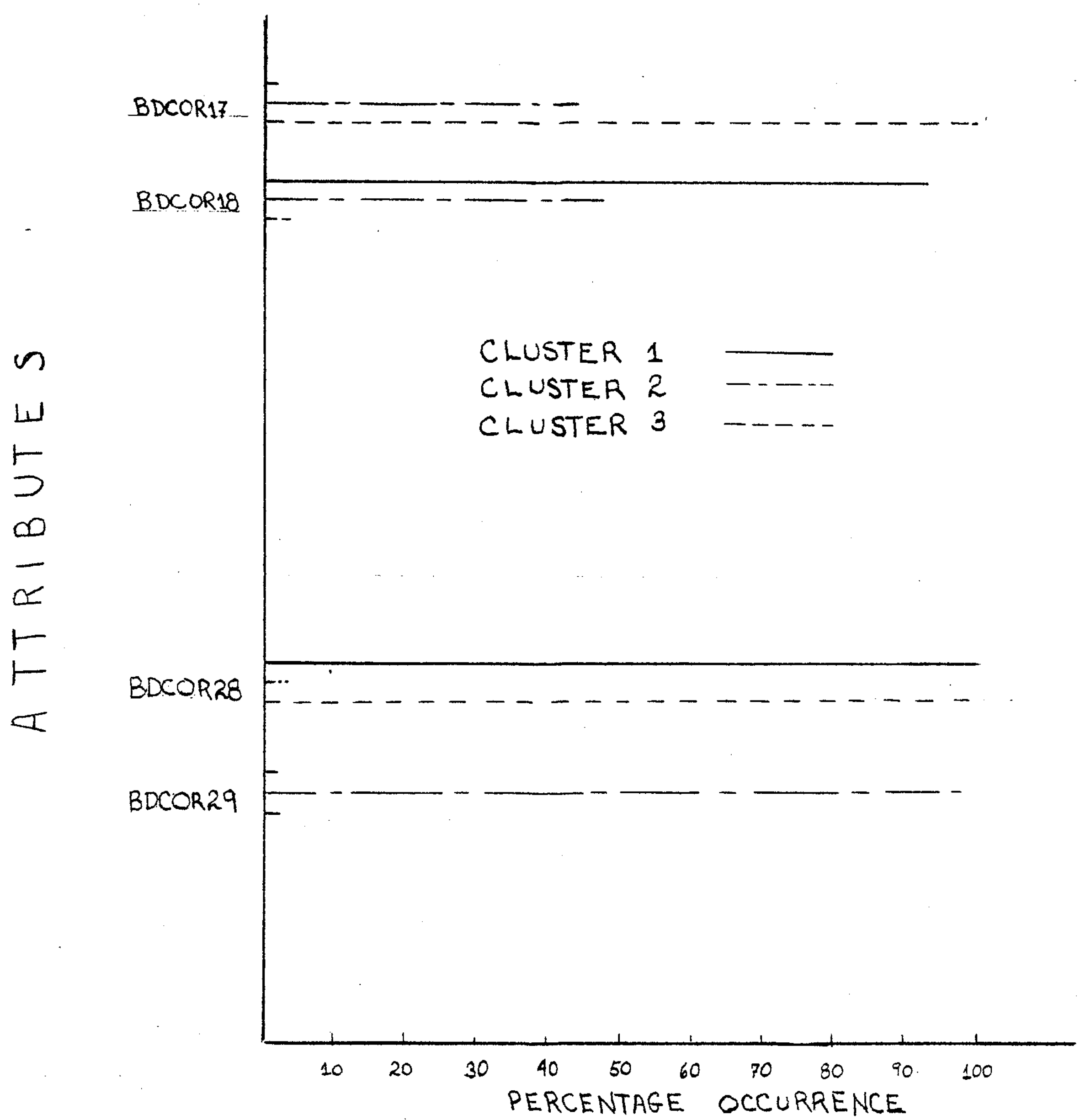

Fig. 14. Percentage occurrence of BDCOR17, BDCOR18, BDCOR28, and BDCOR29 in the DIVIDE 3-cluster classification in Trial 5

in the RELOCATE RIP-10 analysis as successive similarity coefficients show no sharp increases (Fig. 15). Similarity coefficient change at each division of SILPOT in the DIVIDE analysis is erratic, and there are several reversals (Fig. 15). Reversals imply that the distance between 2 newly-formed clusters is less than that measured between clusters formed in the preceding division (Clifford and Stephenson 1975:111). The largest increase in coefficient value between levels occurs in the division of 2 clusters into three. Sizes of the 3-cluster classification were 1 vessel each for Clusters 1 and 2, and 103 for the third. Attributes divided in these 2 steps were second row interior punctates (BDCOR10) and third row exterior punctates (BDCOR8), both near universally absent attributes. The subsequent division of 3 clusters into 4 also resulted from the division of another near-universally absent attribute, incised line (BDCOR32), which also formed a single-entity cluster. The entire analysis was characterized by this pattern of separating small clusters from the main body of the sample.

Comparison of Tables 19 and 20 shows the pattern of splinter cluster formation produced by DIVIDE at 5 successive division levels to be mirrored by a complementary pattern of combining small clusters into a dominant cluster in the RELOCATE RIP-10 analysis. Results of DIVIDE suggest this pattern to be largely the action of the series of attributes which show only slight variations in frequency of occurrence.

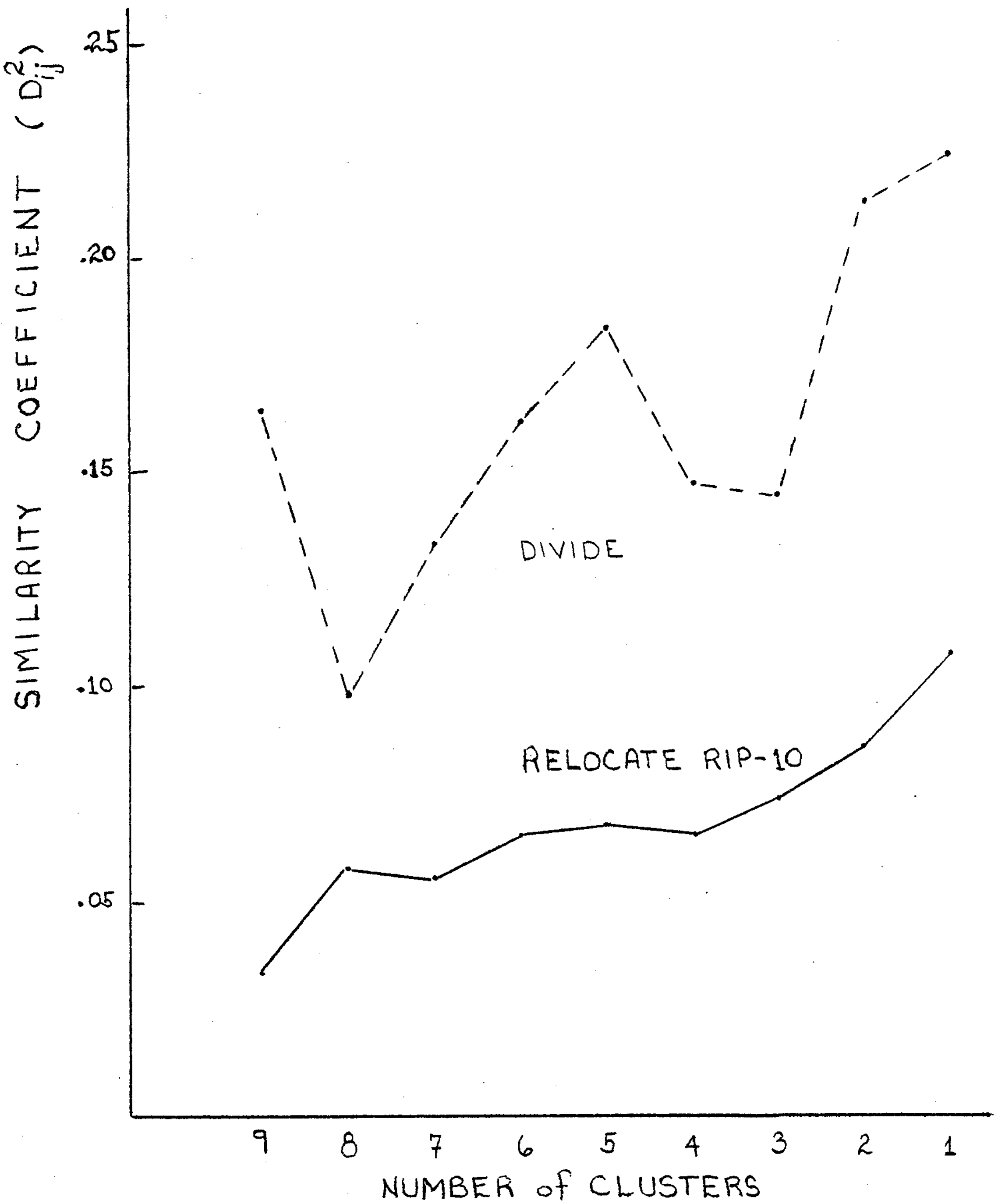

Fig. 15. Similarity coefficient curves for DIVIDE and RELOCATE RIP-10 in Trial 7

TABLE 19. Comparison of Cluster sizes in successive divisions of procedure DIVIDE in Trial 7.

Division Level	Cluster Size				
1	105				
2	1	104			
3	1	1	103		
4	1	1	1	102	
5	1	1	1	99	3

TABLE 20. Comparison of Cluster sizes in successive fusions of procedure RELOCATE RIP-10 in Trial 7.

Fusion Level	Cluster Size				
1	105				
2	102	3			
3	95	3	7		
4	28	67	3	7	
5	24	58	13	3	7

Trial 8

Objective: To evaluate the reduced data matrix with a variance-free procedure.

Method: Subject the data matrix used in Trial 7 to analysis with MODE.

Results and Discussion: MODE produced only 1 classification of 5 clusters in this analysis. Cluster sizes were 62, 20, 2, 7 and 14. The distribution of cluster sizes is similar to that obtained by RELOCATE (24, 58, 13, 3 and 7) at the same fusion level in the preceding experiment, but a contingency table comparison of these classifications (Table 21) shows little overlap in cluster membership and no conclusion concerning the classification can be made.

Both Trials 7 and 8 show distortion of vessel grouping persisted with the inclusion of near-constant valued attributes in the attribute list. In order to overcome this 9 (Table 22) of the 11 attributes which attained interquartile frequences were selected for use in the next trials. The 2 attributes not selected were slight bossing (BDCOR18) and round lips (BDCOR29), the logical correlates already eliminated. This reduction, aside from directly omitting certain information from the analysis, also had the effect of pooling measurements for some related sets of attributes. For example, the negative scoring of round punctates (BDCOR13) implied the presence of elongate (BDCOR14), lunate (BDCOR15), or rectangular (BDCOR16) punctates or when in combination with negative scores for second row punctate (BDCOR7) and pronounced Bossing (BDCOR17), implied the absence of punctates altogether. Information was lost in the few cases where round and rectangular punctates appeared on the same vessel.

TABLE 21. Contingency table comparison of the RELOCATE RIP-10 classification from Trial 7 and the MODE classification from Trial 8.

MODE	RELOCATE					Total
	1	2	3	4	5	
1	10	41	4	3	4	62
2	1	10	9	0	0	20
3	0	2	0	0	0	2
4	0	5	0	0	2	7
5	13	0	0	0	1	14
TOTAL	24	58	13	3	7	105

Trial 9

Objective: To find decorative classes in SILPOT based on minimum-variance procedures.

Method: Subject to analysis with procedures RELOCATE RIP-10 and DIVIDE the data matrix for 105 vessels measured on 9 binary attributes (Table 22).

Results and Discussion: Although the change of similarity coefficient shows 2 reversals in the RELOCATE analysis, a significant classification is indicated at the 4-cluster level (Fig. 16). Cluster sizes at this fusion level are 23, 5, 68, and 9. For the DIVIDE analysis the change in similarity coefficient closely parallels the plot of values for RELOCATE, but indicates a significant classification at the 5-cluster instead of 4-cluster level. The number of vessels assigned to each cluster is 69, 4, 30, 1 and 1.

Table 23 shows the 2 classifications to be in substantial agreement, but the DIVIDE analysis in the third and fourth divisions used invariant valued attributes to form clusters of 1 member each. Because of this tendency, the RELOCATE RIP-10 classification is the more acceptable as an optimum classification. Attribute profiles for this latter classification (Fig. 17) show little similarity among clusters, suggesting they represent distinct groups. Cluster 1 vessels have a high incidence of smooth lips (BDCOR19) that are tool impressed, but not punctated (BDCOR22). High frequencies of these characteristics also appear in Cluster 2, but this cluster is differentiated from Cluster 1 by many vessels with a second row of exterior punctates (BDCOR7), smoothing of the exterior surface (BDCOR1) and fabric impression of the vessel interior adjacent to the lip (BDCOR24).

TABLE 22. Binary attributes used to measure decorative variation in Trials 9 and 10.

Attribute Code	% Occurrence	Attribute
BDCOR1	33.4	Smoothed Exterior Surface
BDCOR7	28.6	Second Row Exterior Punctates
BDCOR13	72.4	Round Punctates
BDCOR17	40.0	Pronounced Bossing
BDCOR19	35.3	Smoothed Lip
BDCOR20	65.8	Fabric Impressed Lip
BDCOR22	25.8	Tool Impressed Lip (Other than Punctated)
BDCOR24	26.7	Fabric Impressed Lip Interior
BDCOR28	67.7	Flat Lip

TABLE 23. . . Contingency table comparison between the DIVIDE and RELOCATE RIP-10 classifications of Trial 9.

RELOCATE RIP-10	DIVIDE 1	2	3	4	5	Total
1	0	0	21	1	1	23
2	1	4	0	0	0	5
3	68	0	0	0	0	68
4	0	0	9	0	0	9
Total	69	4	30	1	1	105

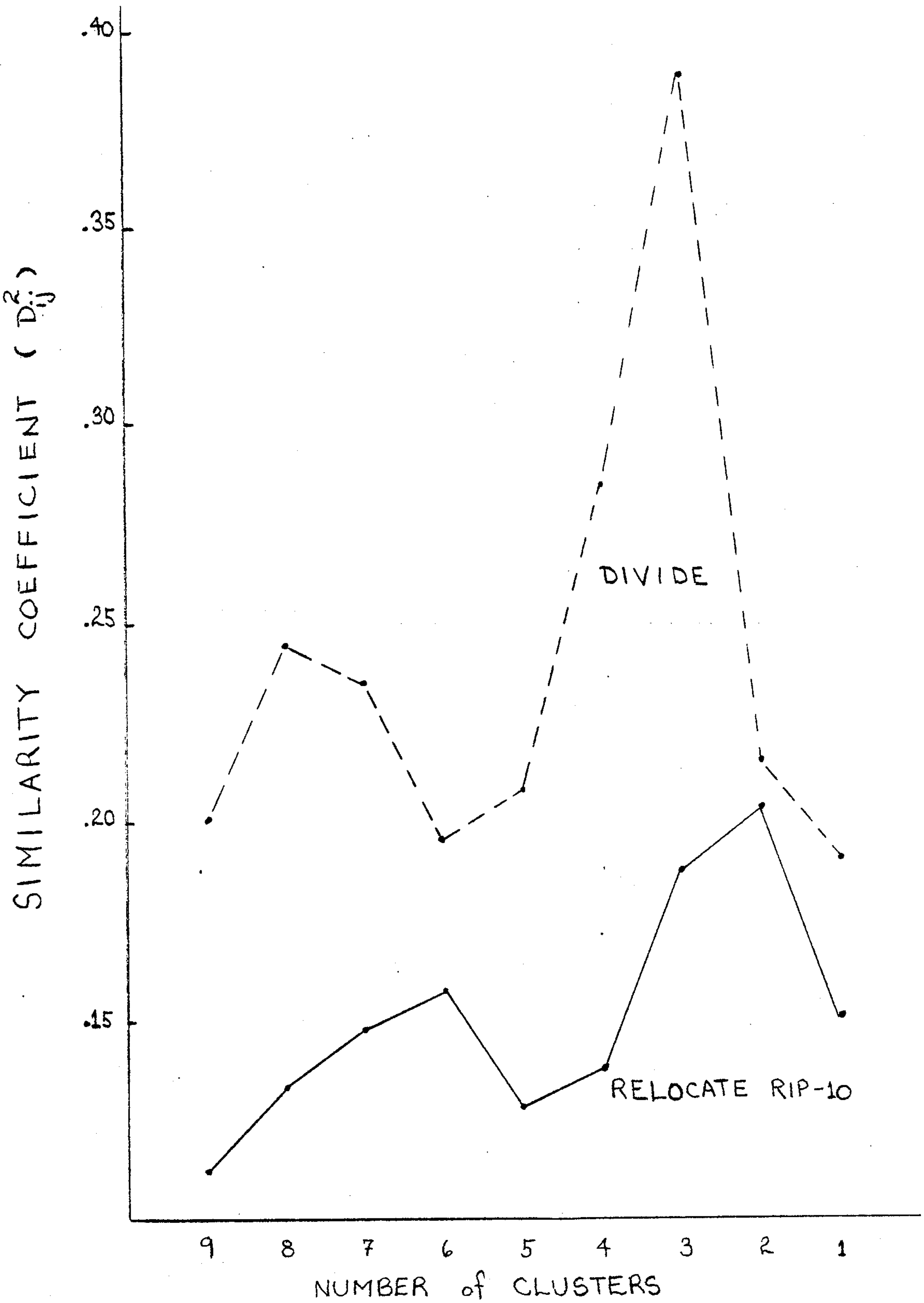

Fig. 16. Similarity coefficient curves for DIVIDE and RELOCATE RIP-10 in Trial 9

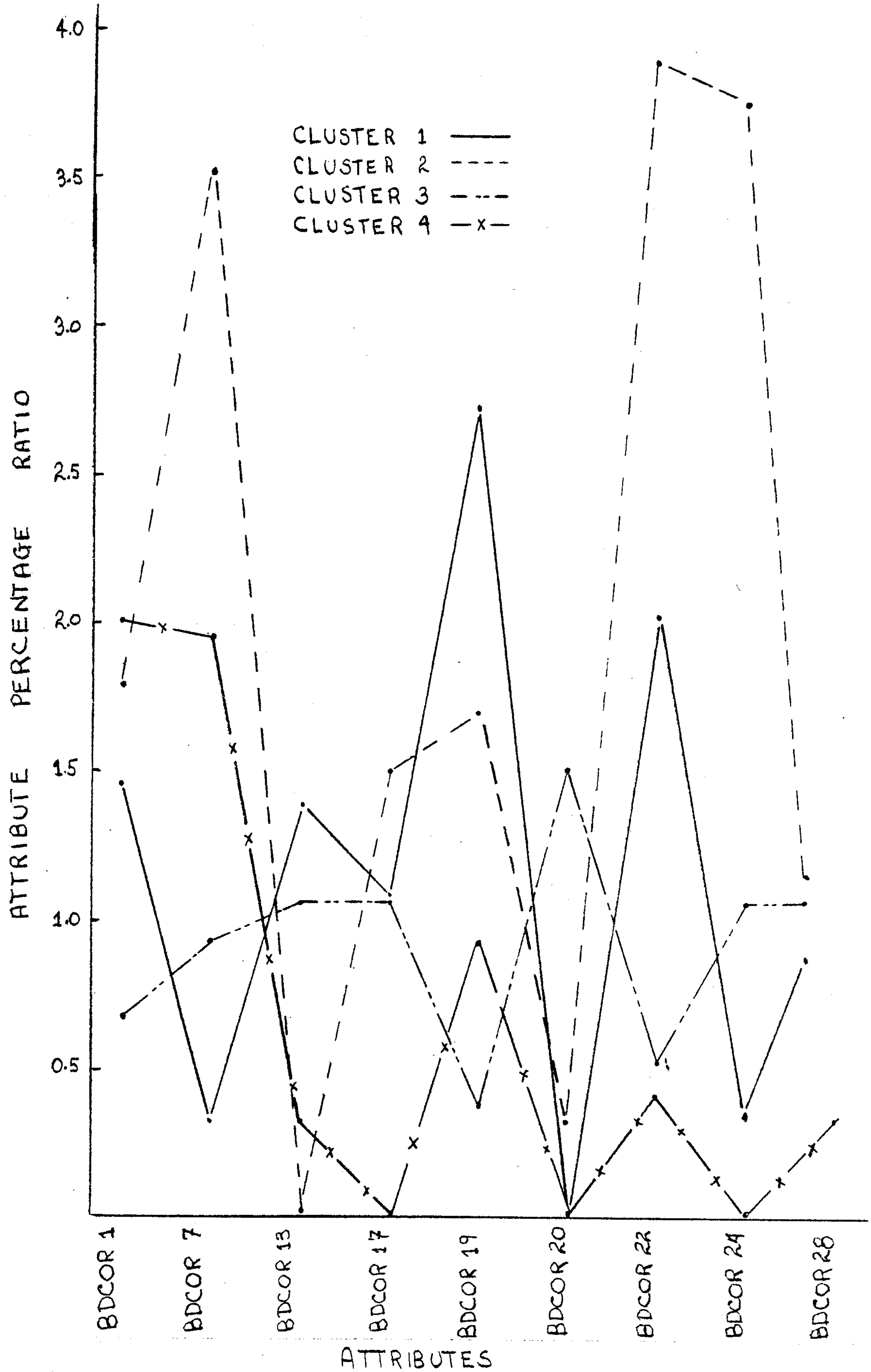

Fig. 17. Attribute profiles for the RELOCATE RIP-10 4-cluster classification in Trial 9

Cluster 3, the largest and most general, is characterized only by fabric impressed lips (BDCOR20). Cluster 4 relates to Cluster 2 by sharing the combination of exterior surface smoothing (BDCOR1) and second row punctation (BDCOR7). These observations suggest that Clusters 1 and 4 are related to one another because of their independent similarities to Cluster 2.

Up to this point no examination of cluster composition has been directed toward the 9 outlier vessels noted in Chapter 4. All nine were grouped into Cluster 3 by DIVIDE and most of them into Cluster 1 by RELOCATE. As a test of the minimum variance procedures to discriminate under-represented groups these results were not encouraging. The problem appears to be with the information loss resulting from the attribute list reduction.

Trial 10

Objective: To find decorative classes of SILPOT using a variance-free procedure.

Method: Subject the same data matrix used in Trial 9 to analysis with MODE.

Results and Discussion: MODE generated 4 classifications after 52 vessels had been introduced. The first of these has 20 clusters and vessels were almost equally divided among the clusters of this classification (Table 24). Following this, the analysis proceeded in a series of nested fusions reducing first to an 11-cluster classification without further introduction of vessels. Cluster 1 dominated this classification in terms

TABLE 24. Cluster sizes of different MODE classifications in Trial 10.

Classification Level	Cluster Size									
20	10 3	4 3	7 9	9 9	6 3	6 5	6 2	7 3	6 2	2 3
11	42 3	21	6	9	9	3	5	2	3	2
2	75	30								

of number of members (Table 24). Further reduction to 2 clusters occurred in a second series of nested fusions. Then 14 additional vessels were introduced and fused immediately into one of the 2 clusters. Introduction of the fifteenth vessel generated the 2-cluster classification (Table 24) and caused fusion into a single cluster completing the analysis.

The salient points in this analysis are:

1. Resolution of the 20-cluster classification.
2. The sequence of nested hierarchal fusions of the 20 clusters into one of 2 final clusters.

The final classification is not evenly proportioned in terms of the number of vessels in each cluster. This classification is also the most comparible to the RELOCATE RIP-10 4-cluster classification of the preceding trial. Although not in complete agreement, the comparison (Table 25) shows substantial overlapping memberships between Clusters 1 and 3, and Clusters 2 and 1 of the MODE and RELOCATE RIP-10 classifications respectively.

It will be recalled from the discussion of the RELOCATE RIP-10 4-cluster classification from Trial 9, Clusters 1 and 4 were related to Cluster 2; this relationship continues in the MODE classification. Over half the possible membership of each of these related clusters in the RELOCATE classification appear together in MODE Cluster 2. While it is not possible to statistically demonstrate the significance or strength of classifactory agreement exhibited in this comparison, it appears reasonable to accept them as consistent in class definition. Attribute profiles for the 2 clusters (Fig. 18) exhibit an inverse relationship. Cluster 1, because of its large size, is diagnostic only on a single attribute: fabric impression on the lip (BDCOR20). On the other hand, Cluster 2 shows high incidences

TABLE 25. Contingency table comparison between the RELOCATE RIP-10 4-cluster classification of Trial 9 to the MODE 2-cluster classification of Trial 10.

RELOCATE	MODE		Total
	1	2	
1	1	22	23
2	2	3	5
3	68	0	68
4	4	5	9
Total	75	30	105

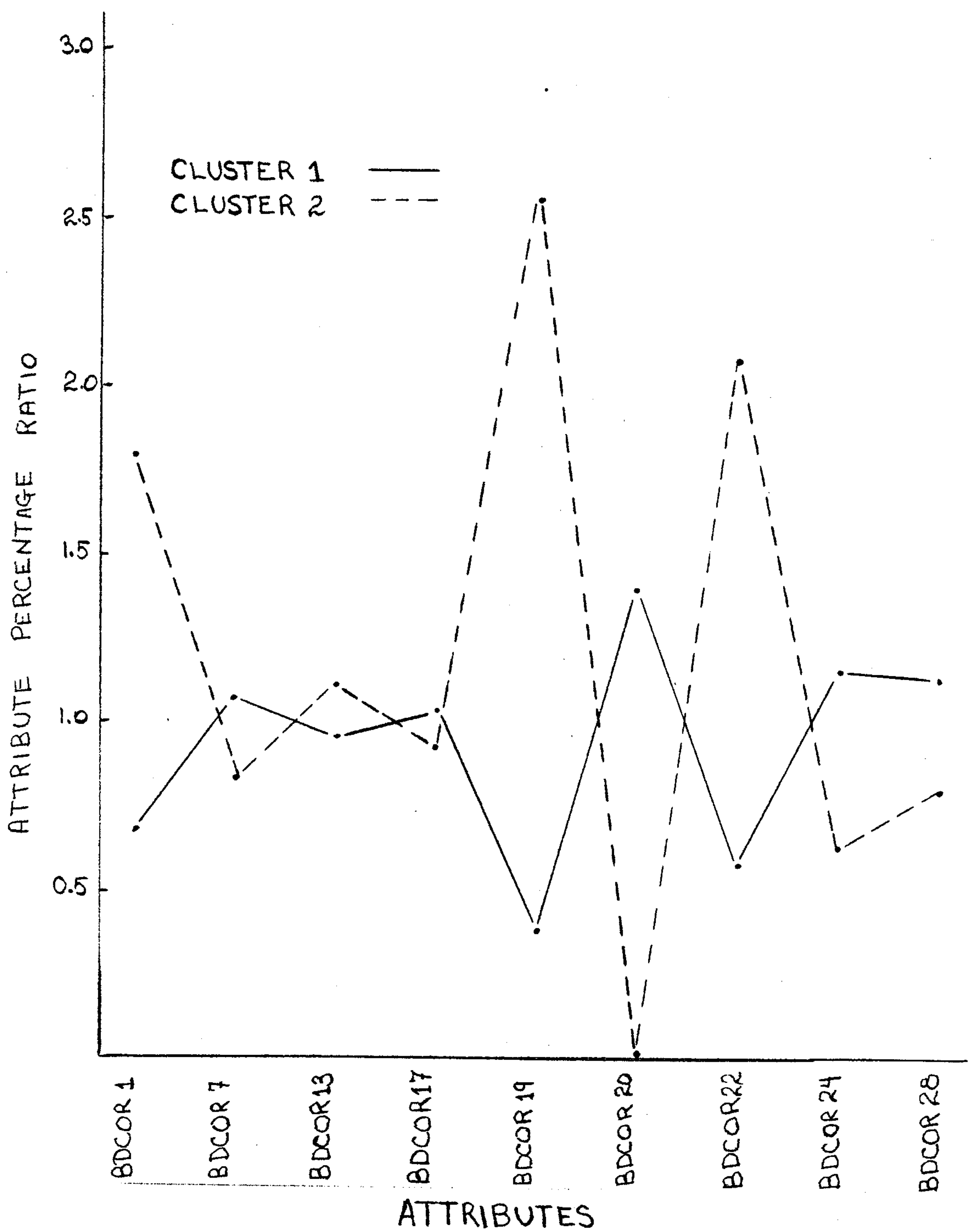

Fig. 18. Attribute profiles for the MODE 2-cluster classification in Trial 10

of smoothed exterior surfaces (BDCOR1) and smooth lips (BDCOR19) decorated with non-punctate tool impressions (BDCOR22). Comparing these profiles with those of the RELOCATE 4-cluster classification in Trial 9 (Fig. 17), it can be seen that the MODE Cluster 2 is most similar to RELOCATE RIP-10 Cluster 1.

The RELOCATE RIP-10 classification did not provide satisfactory differentiation among the Laurel, Blackduck, and miniature vessels. At the most exclusive level of classification, MODE distinguished the miniature vessels most clearly (Table 26) and during the nested fusions from 20 to 11 clusters, it retains this group. In the final classification they were fused into the smaller of the 2 clusters. That these outliers are not isolated into separate clusters is a reflection of the information content recorded by the attributes. Inclusion of them with better represented groups distorts the character profiles of the above described clusters (Anderberg 1973:183). For the final 2 trials, therefore, I selected only the 74 vessels which had been identified as Winnipeg or Grass River Fabric-impressed. Attribute frequencies changed with the sample reduction and 3 attributes were added to the list (Table 27).

Trial 11

Objective: To find decorative classes in the subset of Winnipeg and Grass River Fabric-impressed vessels using minimum-variance procedures.

Method: Subject to analysis a data matrix for 74 vessels measured on 12 attributes with procedures DIVIDE and RELOCATE RIP-10.

TABLE 26. Cluster assignments of outliers in the 3 MODE classifications in Trial 10.

Vessel No.	Identification	Cluster (Size) MODE-20	MODE-11	MODE-2
9	Laurel	2(4)	2(21)	2(30)
24	Black Duck	6(6)	2(21)	2(30)
33	Black Duck	6(6)	2(21)	2(30)
43	Black Duck	10(2)	2(21)	2(30)
89	Black Duck	2(4)	2(21)	2(30)
6	Miniature	16(5)	7(5)	2(30)
71	Miniature	16(5)	7(5)	2(30)
72	Miniature	4(9)	2(21)	2(30)
90	Miniature	16(5)	7(5)	2(30)

TABLE 27. Binary attributes used to measure decorative variation in Trials 11 and 12.

Attribute Code	% Occurrence	Attribute
BDCOR1	21.7	Smoothed Exterior Surface
BDCOR7	29.8	Second Row Exterior Punctates
BDCOR13	74.4	Round Punctates
BDCOR16	16.3	Rectangular Punctates
BDCOR17	43.3	Pronounced Bossing
BDCOR19	25.7	Smoothed Lip
BDCOR20	74.4	Fabric Impressed Lip
BDCOR22	23.0	Tool Impressed Lip (Other than Punctated)
BDCOR23	79.8	Smoothed Lip Interior
BDCOR24	25.7	Fabric Impressed Lip Interior
BDCOR28	69.0	Flat Lip
BDCOR30	24.4	Exterior Fillet

Results and Discussion: The DIVIDE analysis again showed reversals (Fig. 19), but indicated a significant classification at the 4-cluster level. Cluster sizes at this level were 59, 2, 12, and 1. The 2 smaller clusters were divided from the largest by division of constant-valued key attributes produced in the first division. Changes in coefficient values of cluster fusions for RELOCATE RIP-10 showed a sharp increase at the fusion of 2 clusters into 1 (Fig. 19) indicating the 2-cluster classification to be of interest. Cluster sizes are uneven; Cluster 1 has 6 members and Cluster 2 has 68. Attribute profiles of these 2 clusters (Fig. 20) are also dissimilar. The profile for Cluster 2 is almost a straight line, while that for Cluster 1 attains extreme values on 5 of the 12 attributes. Particularly noteworthy is the absence of the 2 attributes for punctate shape, round (BDCOR 13) and rectangular (BDCOR 16), implying the presence of either lunate or elongate forms. Vessels with a second row of punctates (BDCOR7) are frequent.

Trial 12

Objective: To find decorative classes of Winnipeg and Grass River Fabric-impressed vessels based on a variance-free procedure.

Method: Subject the same data matrix used in Trial 11 to procedure MODE.

Results and Discussion: The MODE analysis generated 5 classifications. The largest number of clusters reported in a single classification is 6 with sizes of 40, 7, 14, 8, 2, and 3. This classification was generated after 54 vessels were introduced. The subsequent 5 steps in the analysis consisted of Clusters 1, 2, 3, 5 and 6 becoming nested into a 2-cluster

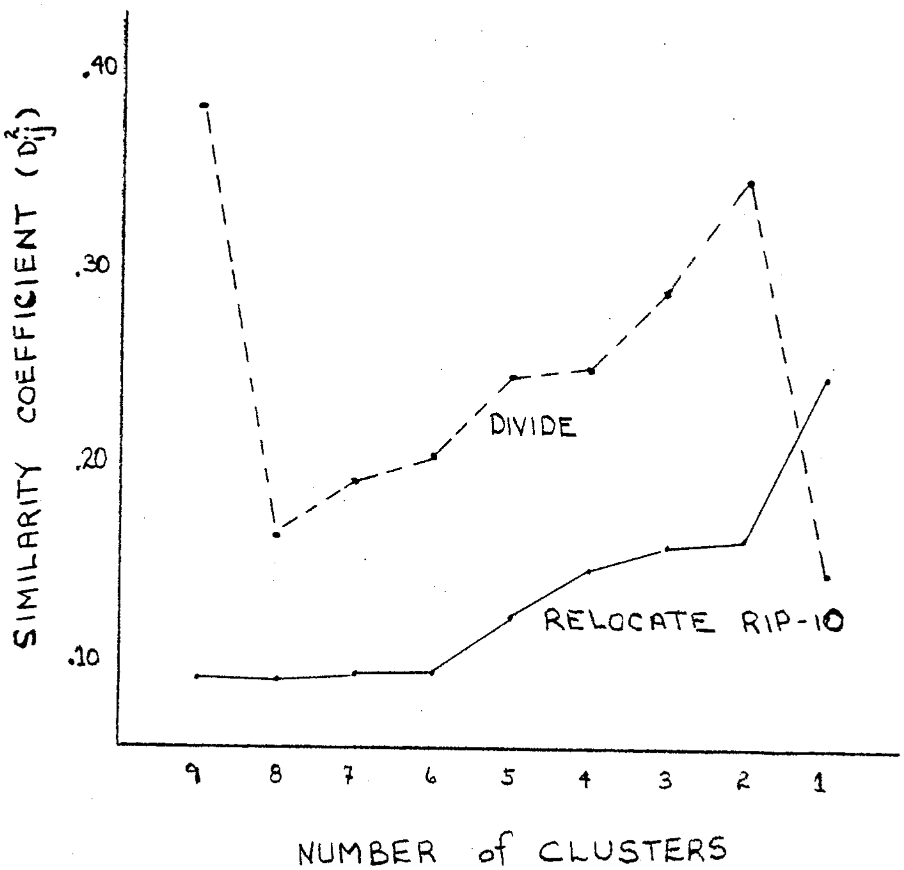

Fig. 19 Similarity Coefficient curves for DIVIDE and RELOCATE RIP-10 in Trial 11.

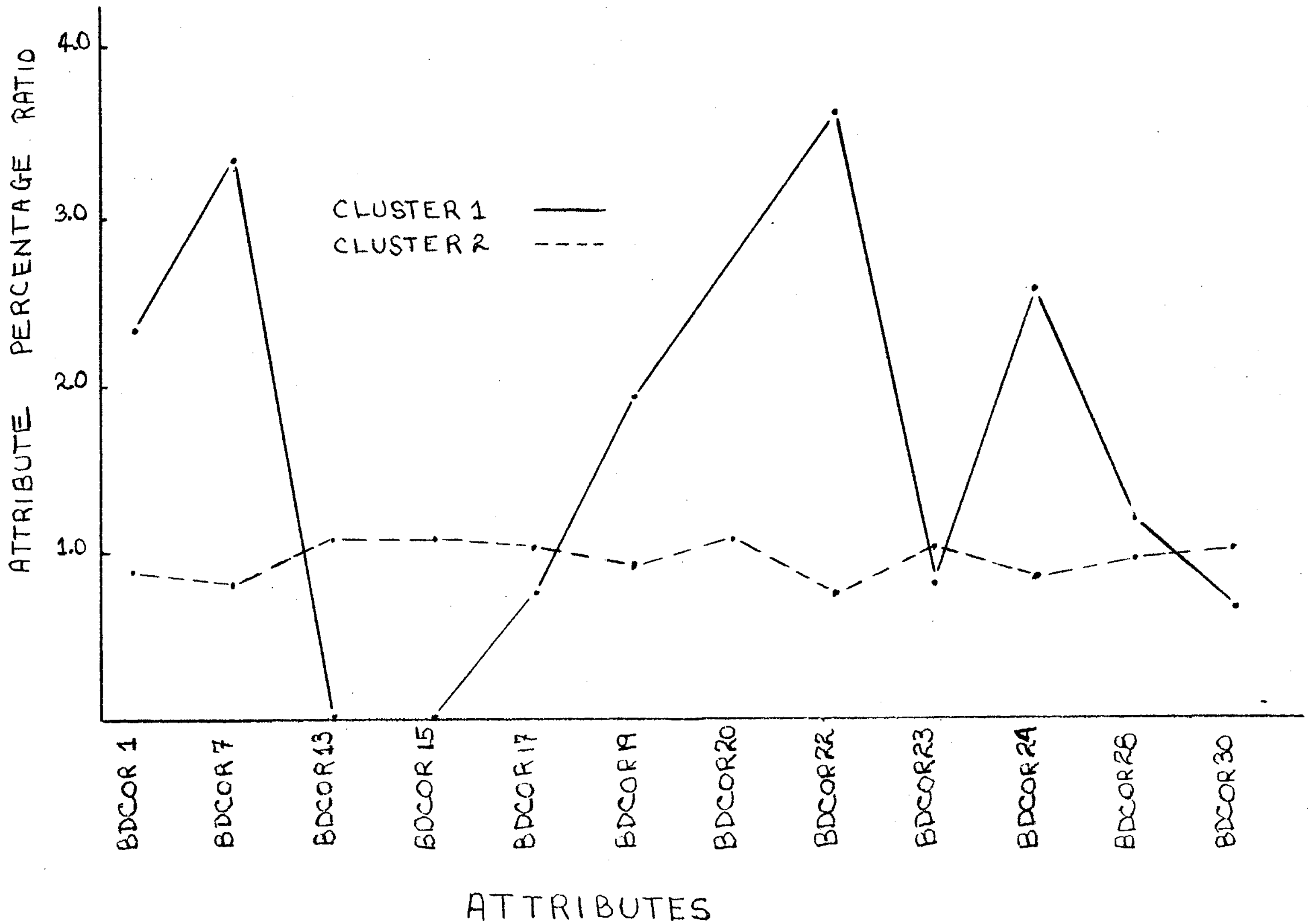

Fig. 20 Attribute profiles for the RELOCATE RIP-10 2-cluster classification in Trial 11.

classification with 66 and 8 members each.

Because of the hierarchical relationship between the first and last classifications, the latter was chosen for comparison (Table 28) with the 2-cluster RELOCATE RIP-10 classification of Trial 11. Conjoint membership in the smaller clusters in each classification is only 2 vessels. Comparison of the attribute profiles for the 2 clusters in this classification (Fig. 21) with those of the previous Trial (Fig. 20) shows discrepancies between the 2 smaller clusters. In the RELOCATE RIP-10 classification the smaller cluster has high occurrence of a second row of punctates (BDCOR7) in contrast to a balanced occurrence of this attribute in the MODE classification. The smaller MODE cluster is only diagnostic in the occurrence of rectangular punctates (BDCOR16) in contrast to its non-occurrence in the RELOCATE RIP-10 Cluster 1. Other contrasts can be seen in the comparisons of tool impressed lips (BDCOR22) and fabric impressed lip interiors (BDCOR 24).

Because both MODE and RELOCATE RIP-10 respectively group over 90% of the vessels into a single cluster, and both find 2 classes they may be considered as representing a robust classification of vessel decoration for the selected sample. These numerically smaller groups are not consistent between the 2 classifications which makes their interpretation difficult; they may be an under-represented group in the sample, or reflect spurious correlations arising from attribute reduction.

Summarizing the last 4 trials (Table 29), no clear pattern of grouping emerges; each analysis finds a different arrangement of vessels. The Index of Similarity decreases in value with the reduction of vessels between

TABLE 28. Contingency table comparison between the RELOCATE RIP-10 classification in Trial 11 and the MODE classification in Trial 12.

MODE	RELOCATE		Total
	2	1	
1	62	4	66
2	6	2	8
Total	68	6	74

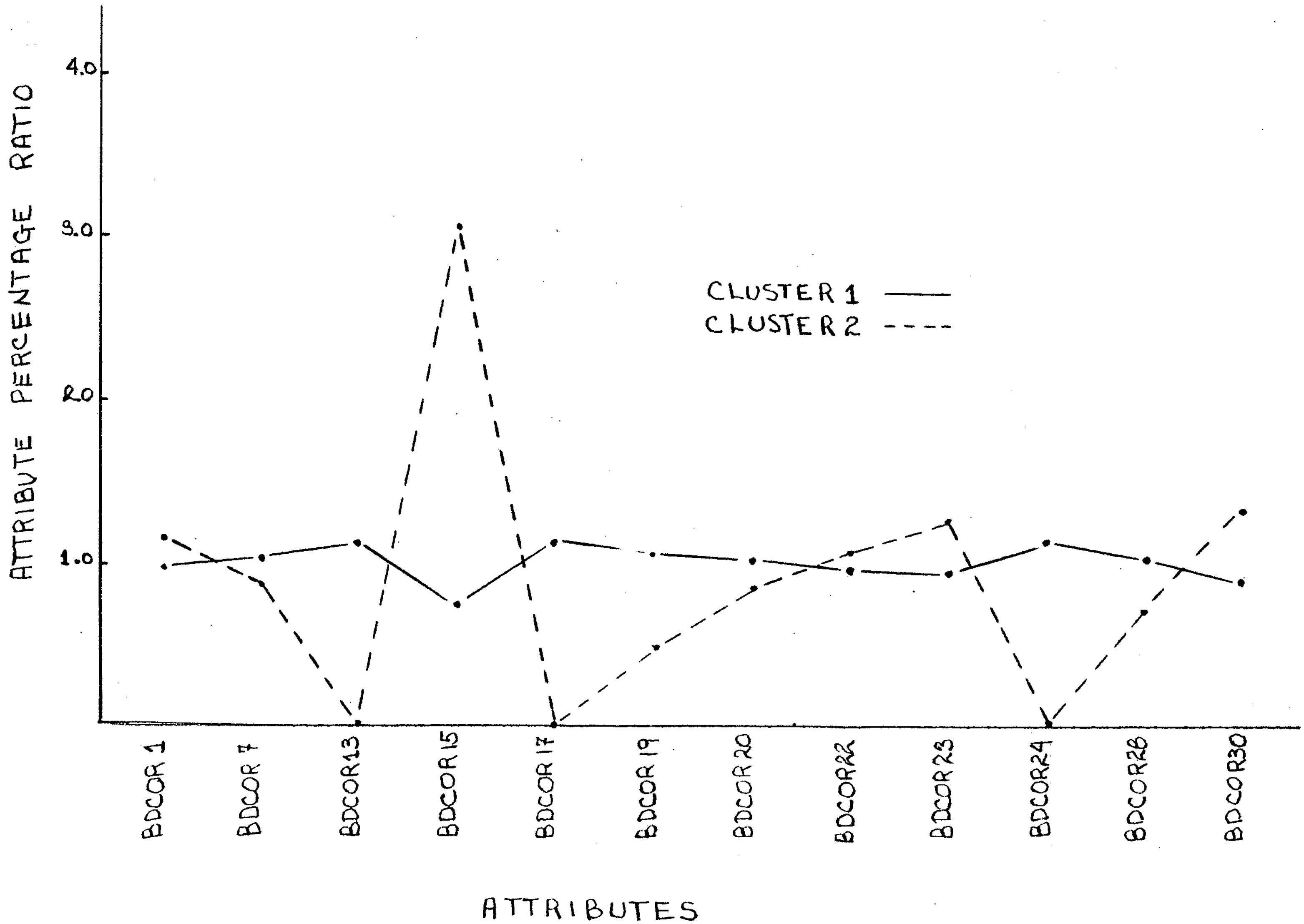

Fig. 21. Attribute profiles for the MODE 2-cluster classification in Trial 12.

TABLE 29. Summary of cluster analysis results of decorative variation.

Trial	Procedure	No. of Vessels	No. of Attributes	No. of Clusters	Cluster Sizes 1	2	3	4	Similarity Coefficient	Maximum Coefficient	Index of Similarity
9	RELOCATE	105	9	4	23,	5,	68,	9	0.139	9	.015
9	DIVIDE	105	9	5	69,	4,	30,	1, 1	0.210	9	.0316
10	MODE	105	9	20-11-2	75,	30			--	--	--
11	RELOCATE	74	12	2	6,	68			0.168	12	.014
11	DIVIDE	74	12	4	59,	2,	12,	1	0.251	12	.020
12	MODE	74	12	6-2	66,	8			--	--	--

trials 10 and 11 and in all cases the Index values approach the complete similarity value given for the Index. A tendency for the number of clusters per classification to decrease is also coincident with sample reduction. All 6 classifications are dominated by 1 cluster to which most of vessels are assigned; the lowest percentage in assignment is 64.7% for the RELOCATE RIP-10 classification in Trial 9. These observations lead to the conclusion that there is almost uniform taxonomic correlation in the decorative attributes under study.

CHAPTER VI

CONCLUSIONS

In concluding this study, I shall reiterate the objective which was to see if vessel groupings could be found in a sample of pottery from Southern Indian Lake, Manitoba. Recognition of different aspects of formal ceramic variation and the distinction between "imposing" and "deriving" a classification have been key to forming the analytical approach selected. Data from the vessels were collected to separately measure morphological and decorative variation. Cluster analysis procedures were used to analyze the data. These procedures, within limits, derive groupings by seeking out taxonomic correlations among attributes. Minimum-variance procedures were counter-balanced by a variance-free procedure to facilitate interpretation and evaluation of various optimum classifications.

Difficulties were encountered which limit the usefulness of the classifications. For example, incomplete reconstruction restricted comprehensive measurement of vessel morphology. Also, a problem of logical correlation among decorative attributes was encountered which resulted in deleting 2 attributes from analysis. Another problem arose after the data were compiled; 8 decorative attributes were found to be almost invariant. Distortions from this source were observed in an analysis trial and further selection was made of the attributes. This had the effect of deleting information and pooling attributes. The full consequences of these modifications were not clear. Also, the sample itself was not drawn as a statistical representation of any population.

However, because of its size, over a hundred vessels, and because of some distinctive variation in visual terms, it was studied as a population.

Despite these problems, groupings in both categories of variation were found. The most prominent were morphological groups representing eliptical plates and other circular orifaced vessels. Some evidence for additional grouping in this latter class was found, but the classifications were not robust or stable and differences were slight. After screening and eliminating attributes distorting the analysis of vessels into decorative classes, it was found that a number of groups were determinable, but again the analyses did not yield stable results, and there was a tendency for the majority of vessels to be grouped together in single clusters by each optimum classification. Definition and characterization of these groups would be premature.

The analyses show there is potential for finding groups which are not the same as those derived by arbitrary categorization.

> The value of exploratory cluster analysis is primarily in the tendency for new arrangements of data units or variables to suggest relationships and principles previously unnoticed. The substantive results are not the output of the computer but the new ideas prompted in the analyst's mind (Anderberg 1973:19).

This study was thus undertaken as a necessary step in establishing the nature of formal ceramic variation in Southern Indian Lake ceramics. Any stable grouping eventually established using this approach and these techniques will have the advantage of being rooted in patterns of taxonomic correlations which may be the products of, and therefore evidence for, the cultural system responsible.

The next stage of the strategy will require conducting analyses with less restrictive programing limitations on an expanded data base for the Southern Indian Lake material and on other regional samples. Steps which can be taken to expand the data include definition of additional attributes and increasing sample size. Caution will have to be exercised in this process so that the problems creating analysis distortions such as those encountered in this study are avoided. If possible, samples drawn from narrower time periods should be selected over samples representing longer periods. Rather than continue in generating classifications which yield visually distinctive classes like the jars and plates in SILPOT, cluster analysis might be more profitably applied to each group separately in search of less obvious grouping patterns. Another avenue of investigation is to form composite analytical samples from several regional samples and ascertaining similarities and differences in morphology and decoration at a broader geographic scale. In this way, by investigating and establishing the nature of ceramic variation, more insightful cultural reconstruction and understanding of cultural processes for the Late Prehistoric Period of the forest regions of central Canada will be possible.

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APPENDIX 1. Catalogue identification of SILPOT vessels.

SILPOT VESSEL NUMBER	SIL SITE SURVEY NUMBER	RIM SHERD CATALOGUE NUMBER	SILPOT VESSEL NUMBER	SIL SITE SURVEY NUMBER	RIM SHERD CATALOGUE NUMBER
1	1	19	41	54	3
2	132	87	42	181	303
3	132	39	43	127	384
4	132	119	44	127	834
5	00	505	45	127	207
6	2	108	46	257	13731
7	1	644	47	54	18863
8	2	191	48	54	12710
9	1	748	49	54	12467
10	1	1136	50	54	13882
11	36	2	51	54	17697
12	34	151	52	54	18978
13	35	165	53	54	18804
14	37	5	54	54	18402
15	184	339	55	54	18899
16	54	11208	56	54	17637
17	37	66	57	54	2061
18	51	2556	58	54	613
19	51	2753	59	54	686
20	53	40	60	54	3586
21	51	4073	61	54	15767
22	53	12	62	54	3248
23	51	4066	63	54	614
24	51	211	64	54	3034
25	51	4087	65	54	3834
26	55	145	66	54	652
27	51	832	67	54	611
28	51	2769	68	54	16387
29	54	1	69	140	17
30	51	1384	70	184	202
31	51	353	71	184	65
32	51	4117	72	184	7
33	51	10248	73	127	779
34	54	10500	74	59	39
35	54	9693	75	111	384
36	54	11122	76	111	508
37	54	6118	77	228	61
38	54	11397	78	208	2
39	54	8684	79	228	62
40	54	6087	80	123	18

APPENDIX 1 . Cont'd.

SILPOT VESSEL NUMBER	SIL SITE SURVEY NUMBER	RIM SHERD CATALOGUE NUMBER
81	123	19
82	228	219
83	127	170
84	130	168
85	144	3
86	129	4
87	130	32
88	232	28
89	269	62
90	269	314
91	269	778
92	182	1073
93	182	2159
94	182	2041
95	182	1870
96	182	2088
97	182	1007
98	182	2284
99	182	1294
100	182	1528
101	182	1735
102	182	584
103	182	2005
104	182	2114
105	141	32

APPENDIX 2 . Computation of squared Euclidean distance coefficients (D^2_{ij}).

For binary data the squared Euclidean distance coefficient is the sum of mismatches in attribute comparisons. Consider the contingency table where a, b, c, and d represent cell frequencies:

		i: Present	i: Absent
j	Present	a	b
	Absent	c	d

Then:

$D^2_{ij} = b + c$ (Anderberg 1973:117)

For continuous measures squared Euclidean distance is the non-directional distance between any 2 entities located as points in a Cartesian coordinate system after transformation to z-scores. Thus:

$$D^2_{ij} = \sum_{k=1}^{k=n} (z_i - z_j)^2 \quad \text{(Everitt 1974:56)}$$

APPENDIX 3. Computation of t-values and F-Ratios

Wishart (1975:72) provides t-values and F-Ratios as part of the results for analyses which involve continuous variables. These are descriptive statistics and provide a means of isolating variables which may be important in the formation of the different clusters in a classification. They are computed as follows:

$$\text{t-value} = \frac{\overline{X}_{ij} - \overline{X}._j}{s.j}$$

where $\overline{X}_{ij}$ = the cluster mean for continuous variable j

$\overline{X}._j$ = the overall sample mean for variable j

and $s.j$ = the overall sample standard deviation

and

$$\text{F-Ratio} = \frac{s^2_{ij}}{s^2.j}$$

where s^2_{ij} = the cluster variance of continuous variable j

and $s^2.j$ = the overall variance of continuous variable j

APPENDIX 4. Percentage occurrence of binary attributes in the DIVIDE 3-cluster classification from Trial 6.

Attribute	Cluster 1	Percentage 2	Occurrence 3
BDCOR 1	33.4	47.1	22.8
2	92.6	82.4	81.9
3	3.8	8.9	11.4
4	0.1	0.1	4.6
5	0.1	17.7	4.6
6	96.3	91.2	100.0
7	37.1	23.6	27.3
8	0.1	0.1	2.3
9	3.8	3.0	0.1
10	3.8	0.1	0.1
11	14.9	0.1	6.9
12	0.1	8.9	4.6
13	85.2	73.6	63.7
14	14.9	11.8	9.1
15	0.1	5.9	11.4
16	7.5	8.9	18.2
17	100.0	44.2	0.1
18	3.8	47.1	93.2
19	26.0	47.1	31.9
20	81.5	47.1	70.5
21	7.5	11.8	11.4
22	14.9	26.5	31.9
23	74.1	88.3	72.8
24	37.1	17.7	27.3
25	3.8	17.7	11.4
26	11.2	17.7	4.6
27	100.0	76.5	95.5
28	100.0	0.1	100.0
29	0.1	100.0	0.1
30	14.9	20.6	25.0
31	7.5	8.9	11.4
32	0.1	11.8	2.3
33	0.1	3.0	0.1