5

Bivalve conjoin analyses: assessing site integrity

Introduction

Conjoin (also refitting or cross-mending) analyses of stone artefact, ceramic and faunal assemblages have long been employed to assess the integrity of various archaeological deposits (see, for example, collected papers in Cziesla et al. 1990; Hofman and Enloe 1992). Only two systematic studies have been conducted in Australia, both concerning rockshelters in the Central Queensland Highlands (Richardson 1992, 1996; Stern 1980; see also Leavesley and Allen 1998). No comparable studies are available for open coastal midden sites despite explicit and implicit reference to this site type as stratigraphically problematic (e.g. Gillespie and Polach 1979; Lourandos 1996, 1997; Roberts 1991; Stone 1989, 1992, 1995). In this chapter I present results of experiments which (a) establish methods for effective conjoin analysis of *Anadara trapezia* (mud ark or Sydney cockle) valves recovered from coastal middens; (b) apply the methods to a case study of the *A. trapezia* assemblage excavated from the mid-Holocene Seven Mile Creek Mound as part of this study; and (c) assess the replicability of these methods through a blind test. The chapter also briefly outlines the range of conjoin analyses undertaken for archaeological purposes and discusses some limitations of these studies. This is the first known application of bivalve conjoin analysis to an archaeological deposit in Australia and the first known application anywhere of these methods to *A. trapezia*. The overall aim of the experiments was to evaluate the potential of using bivalve conjoin analyses to assess the integrity of excavated shell midden deposits on the southern Curtis Coast.

Background

Conjoin analyses in archaeology seek to reassemble objects or parts of objects broken or separated in the past in order to reach understandings beyond those attainable by considering the separated items in isolation. Archaeological conjoin analyses are undertaken for three main purposes (in addition to restorative or conservation work). First, most studies have been undertaken as part of technological analyses of stone artefacts to explicate manufacturing and reduction sequences (e.g. Fullagar 1990; Jones 1987; Leach 1984; for Australian examples see Hiscock 1986b, 1993, in press; Knight 1990; Luebbers 1978). Second, conjoin studies of stone artefacts, ceramics and bone have been used in intra-site spatial analyses to investigate the differential use of space (e.g. Singer 1984; Sullivan et al. 1991; Todd and Stanford 1992). Third, the vertical and horizontal separation of conjoining objects has contributed to understandings of depositional and post-depositional processes, especially assessments of stratigraphic integrity (e.g. Bollong 1994; Cahen 1978; Cahen et al. 1979; Cahen and Moyersons 1977; Villa 1982). It is this last application that is of central concern here.

In Australia, conjoin analyses have had limited application in assessments of stratigraphic integrity. Several studies cite incidental or non-systematic stone artefact conjoin identifications as indicators of stratigraphic integrity (e.g. Flood and Horsfall 1986:19; Fullagar et al. 1996:770). In the first detailed study conducted, Stern (1980) conjoined stone artefacts from the top four excavation units of the Native Well 1 rockshelter in the Central Queensland Highlands to examine vertical displacement within sandy shelter deposits. The analysis indicated that the magnitude of movement of stone artefacts in the deposit could not support the very precise chronology of late Holocene stone artefact technological change proposed by Morwood (1979). Richardson (1992, 1996) conducted an extensive conjoin analysis of the stone artefact assemblage from Kenniff Cave in the Central Queensland Highlands, demonstrating significant vertical and horizontal movement of conjoining artefacts despite a well-defined stratigraphic sequence. Like Stern, Richardson (1996:81) argued that the poor chronological resolution available could not support 'a precise chronology for the appearance or disappearance of implement classes' (see also Mulvaney 1969:213). These findings called into question basic assumptions about the integrity of apparently well-stratified sandstone rockshelter deposits which form the basis of our understanding of the archaeology of eastern Australia.

Open shell middens are frequently cited as lacking integrity, especially in comparison to rockshelter deposits. Indeed, Lourandos (1996:18) has argued that rockshelter deposits provide a 'sounder' dataset as they 'are not subject to the same degree of post-depositional modification as open sites'. Several studies have shown that shell deposits can be (and have been) created and modified by a wide range of taphonomic (Roberts 1991) and depositional processes (Stone 1989, 1992, 1995). Over recent years, a number of approaches to assessing the integrity of coastal shell deposits has been developed, including stratigraphic analyses, fragmentation studies, studies of midden composition (Attenbrow 1992), shell size studies (Carter et al. 1999) and studies of foraminifers (Lilley et al. 1999). However, many of these studies have produced equivocal results. Stratigraphy is often difficult to define in sandy coastal deposits and is often related to differential moisture content and soil profile development rather than depositional processes. Rowland (1994) has also critiqued simplistic models of midden composition showing that items such as pumice, coral and minute gastropods, long-thought to be diagnostic of non-cultural origin of shell deposits are in fact commonly used by hunter-gatherers.

Materials commonly used in conjoin analyses include stone, ceramic, bone, wood, glass and metal (Hofman 1992). Although several studies have reported refitting shell artefacts and engraved shell art (Brown 1981; Hofman 1985; Phillips and Brown 1978), a literature review identified only one study that reported analysis of bivalve conjoins (Koike 1979). Koike investigated the depositional history of a deposit through pairing clam shell valves as part of a shell midden study. Koike (1979:67) argued that, assuming that valve-pairs were connected by ligaments when discarded, the separation of valve-pairs within a deposit may contribute to an understanding of site formation processes and post-depositional movement of shells in the deposit.

Koike (1979) attempted to pair 2,089 whole clam (*Meretrix lusoria*) valves (53% of the total clam assemblage) recorded using three-dimensional plotting from a discrete shell layer (180cm × 80cm × 30cm) in an abandoned Kofun Period dwelling pit in the Natsumidai site, Japan. A total of 380 valve-pairs was identified. A deep occlusion and ridges at the apex coupled with the shared colour pattern of paired *Meretrix lusoria* valves were used to identify valve-pairs. Koike selected whole and unfaded valves from the assemblage and sorted them by side (left or right), length and colour pattern. Analysis proceeded 'by comparing successive right valves to a given left valve until a colour match and tight-closing fit were obtained' (Koike 1979:66). It is unclear at what point manual refitting attempts were abandoned. Seventy percent of the identified pairs were separated by 20cm or less, with most movement evident on the horizontal plane parallel to the slope of the deposit.

Claassen (1998:87) cautioned that the separation of left and right valves in an excavated deposit may not be a valid indicator of the degree of disturbance in a deposit as disarticulated valves can separate upon impact with the ground (see Muckle 1985:62 for results of replication experiments). However, although horizontal separation of paired valves during discard events is likely for this reason, significant vertical separation is not.

Bivalves have a distinct advantage over stone artefacts in conjoin studies owing to the fact that they primarily enter archaeological deposits as food refuse and are unlikely to be reused or recycled as raw materials. Therefore, the assumption that two valves of an articulated bivalve were discarded at the same time is more easily sustained than for stone artefacts or ceramics where significant intervals may elapse between individual discard events (e.g. Lindauer 1992). Although bivalve shells may be used or reused as tools (e.g. scraper) or ornaments (e.g. pendants), the incidences of such artefacts in large shell midden deposits in Australia will be low and edge-damage, use-wear and other analytical studies can be used to identify such uses (e.g. Przywolnik 2003). The validity of individual bivalve conjoins can also be independently checked by, for example, thin section comparison of growth structures, stable isotope analyses and/or radiometric dating of paired valves. Another advantage is that the conjoining material can be directly dated and determination/s obtained on one valve in the pair can be automatically extended to the other to determine deposition rates and/or periods of site disturbance between the two objects. Bivalve conjoins also avoid the problem of assuming that multiple conjoins result from a single breakage event (Larson and Ingbar 1992): there are only two parts to a bivalve conjoin.

Conjoined bivalves are occasionally mentioned in Australian midden studies to establish either cooking and preparation methods, demonstrate the non-cultural origin of deposits or illustrate the integrity of deposits. O'Connor and Sullivan (1994a; Sullivan and O'Connor 1993) have cited the presence of articulated bivalves in shell deposits investigated in the Kimberley region as evidence for a natural origin of the deposit. Robins et al. (1998:112) used the presence of 'hinged' *A. granosa* shells and an internally consistent radiocarbon chronology in support of the integrity of the Bayley Point 3 shell mound in the Gulf of Carpentaria. They argued that these attributes are consistent with a cultural origin for the mounded shell deposits rather than scrub fowl (*Megapodius reinwardt*) nesting activity as the latter is characterised by constant reworking of shell deposits (Mitchell 1993). Elsewhere, Peacock (2000) and Claassen (1991) have associated articulated valves with non-subsistence activities such as raw material for artefact manufacture.

The conjoin analyses presented in this chapter were undertaken to achieve a number of basic objectives:

— To establish reliable criteria and methods for effective valve-pair identification of *A. trapezia* in coastal middens on the southern Curtis Coast through an analysis of the morphological attributes of articulated specimens.
— To apply these methods to a case study to identify conjoins in an excavated assemblage of unarticulated *A. trapezia* valves from the Seven Mile Creek Mound.
— To assess the reliability of these methods through a blind test.
— To assess results in terms of site integrity and formation processes.

General methods and approach

A. trapezia was selected for this valve-pairing study for three main reasons. First, it is present in most recorded shell middens in the region, making this method potentially applicable to a range of excavated assemblages (Ulm 2002b; Ulm and Lilley 1999). Second, this mollusc is still present in tidal estuaries in the region, making studies of live-collected specimens possible. Third, individual specimens exhibit considerable morphological variability, making it unlikely that valves will conjoin tightly unless they are from the same individual.

A. trapezia have slightly asymmetrical valves (Figs 3.1–3.2). Valves exhibit an inflated anterior with tapering to the posterior and ventral margins. Tightly interlocking corrugations occur along the anterior, ventral and posterior margins at the terminations of strong radial ribs. The anterior and posterior lateral teeth are more pronounced than the cardinal teeth, with all enclosed in a rectangular hinge structure (c.1–3mm wide) which is straight along its dorsal edge and concave towards the cardinal teeth on its ventral edge. The presence of numerous interlocking teeth of various sizes, patterns and angles on conjoining hinges precludes tight conjoins unless relatively precise alignment is achieved. Lamprell and Healy (1998:54) note that in juveniles of this taxon, the left valve encompasses (i.e. is slightly larger than) the right valve and the dorsal margin is more angulate at its anterior and posterior terminations.

Attributes for identifying probable conjoins were established by studying articulated archaeological and live-collected specimens. A total of 158 articulated *A. trapezia* was plotted *in situ* during excavation of the Seven Mile Creek Mound (see below and Chapter 6 for site details). Five attributes were measured for each matched pair of whole valves: length, width, height, weight and hinge length (Fig. 3.2). Linear regressions of left versus right valve attributes show that both hinge length and weight are strongly correlated in paired valves (Table 5.1). During 2001 fieldwork, a sample of 10 live-collected *A. trapezia* specimens was obtained from Mort Creek and Round Hill Creek in the study area. Linear regressions of left versus right valve attributes showed that both hinge length and weight were strongly correlated in paired valves (Table 5.2), confirming the results obtained from the sample of archaeological articulated specimens from the Seven Mile Creek Mound.

Table 5.1 Attributes of articulated *A. trapezia* specimens recovered from the Seven Mile Creek Mound in rank order of correlation coefficient. Note that specimens were only included if there was no damage inhibiting accurate measurement of each attribute on either valve in a pair.

ATTRIBUTE	n	RANGE DIFFERENCE	MEAN DIFFERENCE	r^2
Hinge length (mm)	146	0–0.5	0	0.9998
Weight (g)	155	0–3.9	0.8	0.9813
Length (mm)	155	0–3.6	0.7	0.9697
Width (mm)	154	0–6.3	1.4	0.8561
Height (mm)	156	0–2.5	0.8	0.8546

Table 5.2 Attributes of live-collected *A. trapezia* specimens in rank order of correlation coefficient.

ATTRIBUTE	n	RANGE DIFFERENCE	MEAN DIFFERENCE	r^2
Weight (g)	10	0.2	0.8	0.9994
Hinge length (mm)	10	0–0.5	0.1	0.9982
Length (mm)	10	0.1–2.1	0.8	0.9928
Height (mm)	10	0–1.4	0.9	0.9854
Width (mm)	10	0.4–6.4	3.3	0.9127

This examination of articulated *A. trapezia* specimens shows that the hinge and associated articulating teeth are the most symmetrical features of valve-pairs, providing a well-defined rectangular-shaped area amenable to measurement. Weight is the next most strongly correlated variable, despite clear variation in other valve-pair attributes indicating considerable valve dimorphism. Width and height exhibit relatively low correlation coefficients probably owing to more pronounced valve dimorphism in these attributes and minor variability introduced by uncertainty in the selection of measuring points. Hinge length and weight of valves are therefore considered to be the most reliable measures for defining a narrow range of probable conjoins in any given assemblage. Manual refitting of left and right valves can then be used for confirmation, based on the observation that the extent and pattern of teeth on hinges prevents tight or closely fitting pairs unless the valves are from the same individual.

Seven Mile Creek Mound bivalve conjoin analysis

Introduction

The Seven Mile Creek Mound is located on the fringe of Seven Mile Creek, a tributary of Rodds Harbour (see Chapter 6). A single $1m^2$ pit divided into four 50cm × 50cm squares (A–D) was excavated to a depth of 117cm. Excavation proceeded in shallow (<3–8cm), arbitrary excavation units within identified stratigraphic units. Analysis of Square A revealed a deposit dominated by oyster (*Saccostrea glomerata*) and mud ark (*A. trapezia*), dating to 3,600–3,900 cal BP. The presence of numerous articulated *A. trapezia* (n=158) and occasional *Tichomya hirsutus* valves throughout the deposit suggested rapid burial and settling of these shells in the matrix before their ligaments deteriorated and the individuals disarticulated. Dead bivalves articulated by ligaments tend to gape as their adductor muscles are no longer able to pull the valves shut (Cadée 2002; Claassen 1998:18). However, the presence of many closed valves suggests that there is a process whereby at least some shells are forced together, indicating that closing of ligament-articulated valves occurred during discard. An alternative explanation is that valves failed to open during cooking and were discarded. Meehan (1982:97) notes that *A. granosa* do not open easily even after heating, while my observation of *A. trapezia* indicates they are similar in this regard. The presence of these articulated shells *in situ* suggested the possibility that further pairs might be identified through refitting separated valves and that this might contribute to an understanding of site integrity and depositional history. An understanding of the despositional history of the site was considered particularly valuable because the 300 year sequence had no discernible stratigraphic features, although the internally consistent radiocarbon chronology indicated that rapid deposition has occurred at the site in a number of sequential events (see Chapter 6).

Unarticulated valves were not plotted in three dimensions during excavation. Provenance of individual valves has a uniform horizontal error of ±25cm while vertical error ranges from ±3–8cm depending on excavation unit. Given these uncertainties, each valve conjoin set has a different level of vertical resolution, constrained by the size of the excavation units containing the valves. Therefore, the separation distances cited for an individual conjoin set are maximums.

Aims

Conjoin analysis at the Seven Mile Creek Mound was employed to address three specific research issues:

- — To provide a practical application of the criteria and methods for effective valve-pair identification of *A. trapezia* developed on the basis of the morphological attributes of articulated specimens.
- — To establish the degree of site integrity by examining the vertical distribution of identified conjoins through the dated sequence.
- — To contribute to an understanding of site use and occupational intensity.

The null hypothesis based on the radiocarbon chronology (see Chapter 6) is that the c.300 year deposit represents a series of occupational events rather than continuous occupation. Mechanical damage and displacement will thus have had the most impact on the terminal deposits from the previous occupation event. These are also the deposits most likely to be impacted by other agents, such as animal burrowing (Roberts 1991). The structure and circumscribed extent of the Seven Mile Creek Mound enhances the potential of the site to reveal evidence for occupational periodicity and the contemporaneity of deposits. The frequency and distribution of bivalve conjoins within the deposit may therefore be used in some instances to define depositional events in the absence of clear stratigraphic information or to test stratigraphic inferences. More spatially-extensive sites would be expected to exhibit a more diffuse series of loci of repeated occupation activity.

Methods

Largely intact unarticulated *A. trapezia* valves from Square A were separated from the excavated assemblage (n=608) and individually bagged with basic provenance details. Length, width, height, weight and hinge length were measured for each valve (Fig. 3.2). Other valves were excluded from the study owing to the presence of attributes which biased one or more valve measurements (e.g. hinge damage, broken margins, attached oysters etc). The 608 whole valves were sorted by hinge length, weight and side (left or right) in descending order and assigned an arbitrary identification number (1–608). Unlike many stone artefact conjoin analyses which look at the closest material first, this method makes no assumptions about provenance of valve-pairs (i.e. valves from the same unit or adjacent unit were not assumed to have a greater probability of exhibiting conjoins than more distant units). Valve-pairs were identified by manually refitting successive right valves to left valves on a trial-and-error basis until a conjoin was identified. Refitting attempts for an individual valve were abandoned after 10 attempted refits forward and 10 backward from the valve's position on the descending size scale. This procedure was adopted to take into account the range of valve-pair dimorphism observed in articulated specimens, measurement uncertainty and the clumping of size-selected valves within limited size-ranges.

For example, in Figure 5.1 right valve 157 would be compared with left valves 156, 154, 153, 152, 151, 150, 149, 142, 138 and 137 in ascending valve size and with 158, 159, 160, 161, 164, 165, 168, 170, 172 and 173 in descending valve size. This procedure would then be repeated for right valve 162 and so on. Even though right valve 157 was found to pair with left valve 154, the full 20-refit-attempt procedure was undertaken to confirm the validity of the identified valve-pair. This method underestimates the number of conjoining valves that actually occur in the deposit for several reasons. First, any pair of valves where there was ambiguity about the match was rejected. Second, only a very limited amount of time was allocated to the assessment of each potential match (see below). The conjoin analysis of the 608 whole valves involved in the order of 6,000 individual refitting attempts.

Results

A total of 56 valve-pairs was identified in the assemblage, distributed between XU2–24 (Table 5.3). Seventy-nine percent of valve-pairs are vertically separated by less than 10cm, 55% less than 5cm and 98% less than 20cm apart. The small distances separating valve-pairs supports the impression gained from the radiocarbon chronology that shell was deposited in extremely rapid episodes (see below for further discussion).

There is no significant relationship between the size of valves in conjoining pairs and distance separating them, as measured by average hinge length versus maximum valve separation distance (correlation coefficient, r^2=0.1539). This discounts size-sorting as a major determinant of valve position within the deposit and reinforces the proposition that the structural properties of the matrix, constructed of closely interlocked shells, prevented significant post-depositional movement.

#	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147
R		0		0			0	0	0		0	0	0	0	0
L	0		0		0	0				0					
#	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162
R	0							0		**0**					0
L		0	0	0	0	0	0		0		0	0	0	0	
#	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177
R	0			0	0		0		0			0	0	0	
L		0	0			0		0		0	0				0

Figure 5.1 Schematic representation of conjoin identification procedure. 0=individual *A. trapezia* valve. In this matrix, left and right valves are arranged in descending size order. See text for details.

Bivalve conjoin analysis blind test

Introduction

The conjoin analysis provided encouraging results for further valve-pairing studies. However, the potential subjectivity in the identification of valve-pairs during the manual refitting stage indicated that an independent evaluation of the efficacy of the method should be undertaken. A blind test was designed for this purpose based on replicated attributes of valves used in the archaeological case study.

Aims

The objectives of the blind experiment were:

— To assess the reliability of the valve-pairing method applied to the Seven Mile Creek Mound assemblage.

— To identify sources of error in the valve-pairing method.

Methods

An independent collection of live-collected *A. trapezia* was unavailable for the blind test owing to the small size of museum holdings of this taxon. An experimental archaeological set of 500 valves was created with 50 known valve-pairs and 400 unpaired single valves. The control sample of 100 valves that form 50 known articulated pairs was selected from valve-pairs encountered as articulated specimens during excavation of the Seven Mile Creek Mound, Squares A–D. The original 316 valves (158 valve-pairs) in this assemblage were reduced to a sample of 100. Valves from articulated specimens from Square A (44 valves) were excluded as many had been used or modified for radiocarbon dating and stable isotope studies. The remaining valve-pairs were reduced to a sample of 50 by maintaining the hinge size distribution evident in the original sample of 158 valve-pairs. A further 400 valves thought not to form a pair with any other in the sample were selected from valves used in the Seven Mile Creek Mound, Square A case study above. These were arranged in ascending order by height (the attribute with the least significant correlation coefficient), and then assigned an arbitrary reference identification number (1–500) in ascending order of height. The 500 valves were then resorted in ascending order by hinge length, weight and side (as per the archaeological case study above). Refitting methods proceeded as outlined above. This blind test involved in the order of 5,000 individual refitting attempts.

Results
The overall success rate for correct identification of articulated values in the blind test was 94%. Six valves out of 500 (1.2%) were misidentified as conjoins. On re-examination these were rejected as valid conjoins because they did not fit tightly together at both the articulating hinge teeth and the corrugated margins. One misidentified conjoin set actually contained a valve from a known articulated valve-pair. Five valve-pairs were identified as new conjoins in the single-valve dataset. These valve-pairs were confirmed on re-examination (Table 5.4). These pairs were not identified in the previous study. Twenty-two valves (11 valve-pairs) in the 100-valve control sample were not identified as conjoins during the blind test. On re-examination these were clearly conjoins. The vertical position of these valves in the spreadsheet sorted in ascending order by hinge length, weight and side (left/right) shows that all are within 10 valves up and down of each other on the descending size scale and thus the fact that they were missed during the blind test cannot be ascribed to limitations of the methods employed. Thus a total of 28 individual valves out of the 500 in the blind test dataset was either misidentified as conjoins or missed altogether (5.6%).

Discussion

With the additional five valve-pairs identified from the Seven Mile Creek Mound, Square A during the blind test, a total of 20% of the whole *A. trapezia* valve assemblage was refitted (122/608). Up to 80% of the whole *A. trapezia* valves in the assemblage are therefore pair-less. This latter figure must be considered as a maximum, however, given the probability that some conjoins were missed (see below). Although the overall success rate for correct identification of articulated valves was relatively high (94%), the error rate (4.4%) is largely composed of the 11 articulated valve-pairs in the control sample which were missed in the blind test. The blind test demonstrated that the conjoin identification methods adopted were adequate to identify *all* known conjoins present in the blind test assemblage.

Two major factors are thought to have structured the valve-pair identification rate determined through the blind test. The primary factor is the short amount of time spent attempting the manual refit and evaluation of any particular valve-pair. Relatively precise alignment is required to achieve tight interlocking of conjoining valves owing to the presence of numerous interlocking teeth of various sizes, patterns and angles on conjoining hinges. As Larson and Ingbar (1992:151–2) observed, 'the number of refits or conjoins found is directly proportional to the amount of time expended in seeking them'. A secondary factor in the blind test is thought to be the fact that some of the articulated control samples had minor edge-damage that might have biased identification, with otherwise conjoining valves rejected owing to the inability of valves to interlock at the corrugated margins. Given these limitations, the number of conjoins identified in any given bivalve assemblage should be considered a *minimum* as this number will almost certainly underestimate the true number of conjoins in any assemblage. Although theoretically there can only be a finite number of conjoins in any assemblage, limitations of resources allocated to refitting mean that it is unlikely that any but the most thorough and time-consuming analyses will identify every conjoin. The term 'minimum number of conjoins' is therefore adopted to describe the conjoins identified in this study. Given these constraints, no unequivocal statements can be made about the *absence* of conjoins or proportion of conjoins to non-conjoins in any given assemblage.

Combining the results of the initial conjoin analysis with those of the blind test, a total minimum number of conjoins of 61 was identified from the Seven Mile Creek Mound, Square A. The distribution of conjoins is positively skewed with most pairs (55.74%) separated by 5cm or less and over 80% separated by 10cm or less. Only 3.28% of the identified conjoins are separated by

Table 5.3 Identified *A. trapezia* conjoin sets, Seven Mile Creek Mound, Square A.

	XU					
CONJOIN SET	L	R	MIN. SEPARATION (cm)	MAX. SEPARATION (cm)	MID-POINT (cm)	± (cm)
Set 1	21	21	0	3.6	1.8	1.8
Set 2	21	18	7.1	16.86	11.98	4.88
Set 3	21	21	0	3.6	1.8	1.8
Set 4	20	19	0	7.1	3.55	3.55
Set 5	21	23	3.48	10.4	6.94	3.46
Set 6	21	20	0	7.44	3.72	3.72
Set 7	21	24	6.8	13.36	10.08	3.28
Set 8	9	4	13.62	21.24	17.43	3.81
Set 9	19	21	3.84	10.7	7.27	3.43
Set 10	21	21	0	3.6	1.8	1.8
Set 11	20	20	0	3.84	1.92	1.92
Set 12	3	3	0	3.28	1.64	1.64
Set 13	12	9	7.44	14.94	11.19	3.75
Set 14	20	21	0	7.44	3.72	3.72
Set 15	9	9	0	3.84	1.92	1.92
Set 16	20	20	0	3.84	1.92	1.92
Set 17	20	18	3.26	13.26	8.26	5
Set 18	4	2	3.28	10.04	6.66	3.38
Set 19	20	20	0	3.84	1.92	1.92
Set 20	19	21	3.84	10.7	7.27	3.43
Set 21	18	20	3.26	13.26	8.26	5
Set 22	20	20	0	3.84	1.92	1.92
Set 23	13	13	0	4.68	2.34	2.34
Set 24	20	20	0	3.84	1.92	1.92
Set 25	13	13	0	4.68	2.34	2.34
Set 26	20	22	3.6	10.92	7.26	3.66
Set 27	9	10	0	7.22	3.61	3.61
Set 28	21	21	0	3.6	1.8	1.8
Set 29	3	2	0	6.26	3.13	3.13
Set 30	20	21	0	7.44	3.72	3.72
Set 31	2	2	0	2.98	1.49	1.49
Set 32	4	3	0	7.06	3.53	3.53
Set 33	10	10	0	3.38	1.69	1.69
Set 34	3	4	0	7.06	3.53	3.53
Set 35	11	10	0	7.44	3.72	3.72
Set 36	19	22	7.44	14.18	10.81	3.37
Set 37	16	16	0	4.64	2.32	2.32
Set 38	13	13	0	4.68	2.34	2.34
Set 39	3	2	0	6.26	3.13	3.13
Set 40	20	20	0	3.84	1.92	1.92
Set 41	2	2	0	2.98	1.49	1.49
Set 42	10	10	0	3.38	1.69	1.69
Set 43	19	19	0	3.26	1.63	1.63
Set 44	20	20	0	3.84	1.92	1.92
Set 45	3	3	0	3.28	1.64	1.64
Set 46	6	5	0	6.64	3.32	3.32
Set 47	4	4	0	3.78	1.89	1.89
Set 48	24	24	0	2.96	1.48	1.48
Set 49	3	3	0	3.28	1.64	1.64
Set 50	5	5	0	2.98	1.49	1.49
Set 51	4	4	0	3.78	1.89	1.89
Set 52	4	3	0	7.06	3.53	3.53
Set 53	23	23	0	3.32	1.66	1.66
Set 54	22	23	0	6.8	3.4	3.4
Set 55	4	4	0	3.78	1.89	1.89
Set 56	18	18	0	6.16	3.08	3.08

Table 5.4 Additional *A. trapezia* conjoin sets identified during the blind test, Seven Mile Creek Mound, Square A.

	XU					
CONJOIN SET	L	R	MIN. SEPARATION (cm)	MAX. SEPARATION (cm)	MID-POINT (cm)	± (cm)
Set 57	21	21	0	3.6	1.8	1.8
Set 58	21	19	3.84	10.7	7.27	3.43
Set 59	20	20	0	3.84	1.92	1.92
Set 60	21	21	0	3.6	1.8	1.8
Set 61	19	19	0	3.26	1.63	1.63

more than 15cm (Table 5.5, Fig. 5.2). The site, therefore, appears to exhibit a high degree of stratigraphic integrity. This impression is reinforced when it is considered that the lack of more detailed resolution means that these maximum separation measurements probably overestimate the actual separation distance between valves in many instances.

The large number of articulated valve-pairs encountered both *in situ* (n=22) and through conjoin analysis (n=61) in the Seven Mile Creek Mound, Square A suggest that a large proportion of the *A. trapezia* assemblage was still connected by ligaments or otherwise closely associated when discarded. Although horizontal data are not available, I suggest that both vertical and horizontal movement is largely explicable as a function of some valves becoming separated upon discard and moving down the slope formed by the margins of the mounded deposit. The characteristics of the matrix mean that the separation of valves forming valve-pairs is probably largely a function of deposition events rather than post-depositional movement of valves. If this proposition is accepted, the distribution of valve-pairs can contribute to an understanding of the sequence and duration of depositional events and therefore periodicity of occupation.

Other lines of evidence can be used in conjunction with bivalve conjoin analyses to investigate aspects of site integrity. In simulated heating and mechanical destruction experiments, Robins and Stock (1990) found that *A. trapezia* was resilient up to 600°C, equivalent to a small camp fire, but showed marked susceptibility to mechanical destruction (fragmentation) under higher experimental temperatures of 800–1,000°C. Such high temperatures are not thought to be achievable using the fuel resources available to foragers in southeast Queensland (Robins and Stock 1990:86–7). This suggests that in the absence of very high temperatures, fragmentation of *A. trapezia* will be largely the result of mechanical damage to the shell itself. The high proportion of whole *A. trapezia* shells encountered, the virtual absence of charcoal and the lack of evidence for burning on the surface of examined shells does not suggest extended heating during cooking, direct disposal into fires or that shells were later exposed to fires built close to discarded shells (see Robins and Stock 1990:89). There is no strong correlation between the abundance of bivalve conjoins in any area of the deposit (as defined by XU) and differential fragmentation rates (compare Figs 5.3 and 5.5). In fact, the low fragmentation rate of *A. trapezia* suggest that shells in the deposit were not exposed to temperatures above 600°C or significant mechanical damage owing to post-depositional agents acting on the deposit (e.g. trampling etc).

The vertical distribution of overlapping conjoin sets indicates that the site can be divided into at least two separate sequences of accumulation (XU2–12, XU18–24), separated by zones that may also be associated with these events (Fig. 5.3). The internal consistency of the radiocarbon chronology coupled with the apparently internal coherence of multiple

Table 5.5 Summary of maximum distance separating all conjoined *A. trapezia* valve-pairs, Seven Mile Creek Mound, Square A.

DISTANCE	#	%
0–5cm	34	55.74
5–10cm	15	24.59
10–15cm	10	16.39
15–20cm	1	1.64
20–25cm	1	1.64
Total	61	100

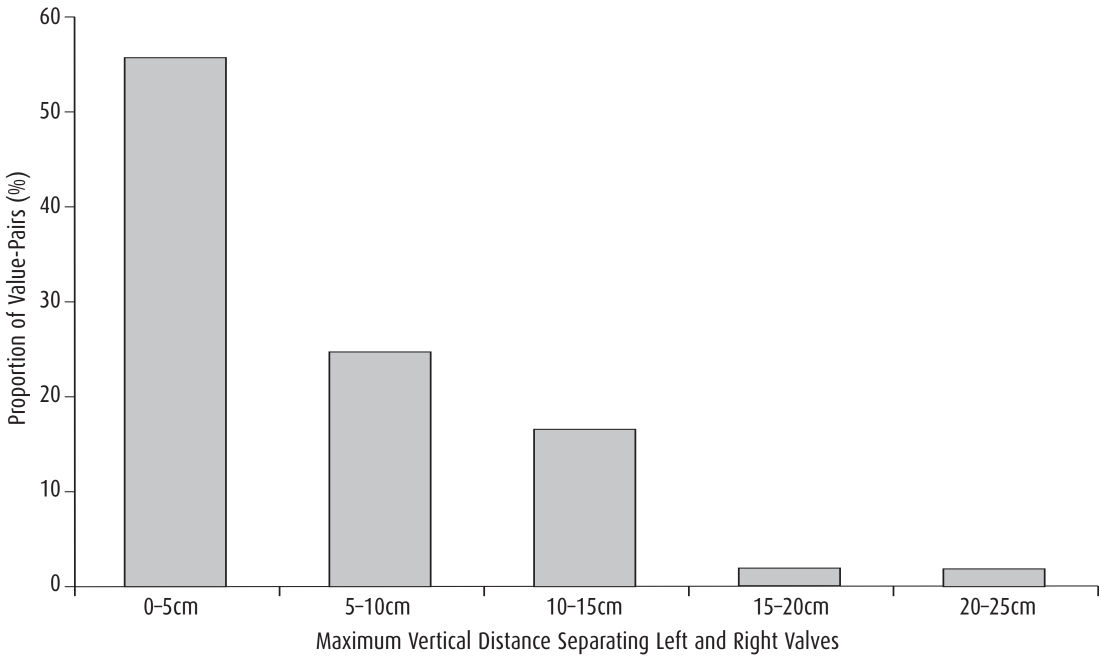

Figure 5.2 Maximum vertical distance separating all conjoined valve-pairs, Seven Mile Creek Mound, Square A.

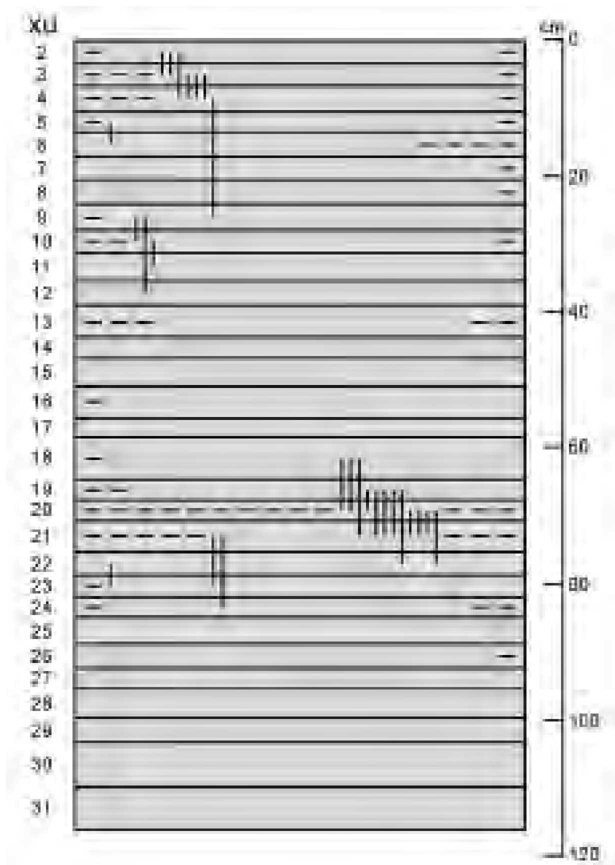

Figure 5.3 Distribution of identified *A. trapezia* valve-pairs (n=61), Seven Mile Creek Mound, Square A. An additional 22 valve-pairs encountered as articulated specimens during excavation are shown as short horizontal lines down the right hand side of the figure (see Chapter 6). Line termination points indicate the vertical mid-points of the excavation units from which conjoining valves were recovered. Short horizontal lines indicate valve-pairs identified within excavation units. Not to scale on the horizontal axis.

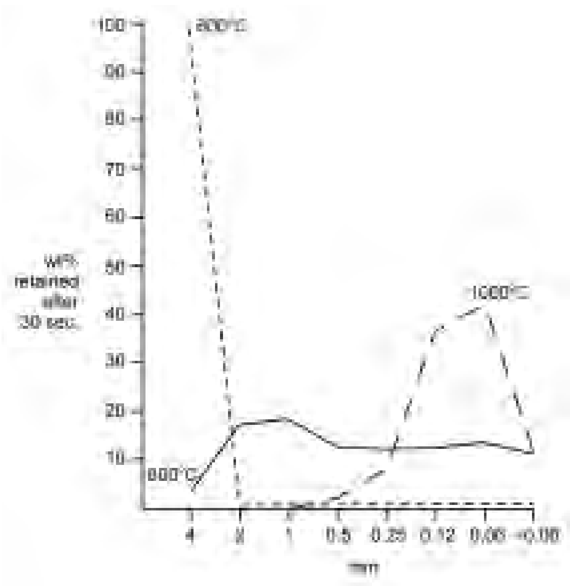

Figure 5.4 Particle size distribution of *A. trapezia* after heating at various temperatures and then mechanical destruction for 30 seconds (after Robins and Stock 1990:98).

conjoined bivalves suggests that the distribution of conjoins may be used as a proxy for layer thickness. As Huchet (1991:46) suggested, the 'presence of a large percentage of conjoinable pieces of bone, stone or other material found within a constricted area can be taken as a sign that deposition occurred within a limited time period or during a single event'.

Conjoin analyses undertaken in this study are restricted to vertical associations in a single 50cm × 50cm test pit. The identification of bivalve conjoins across adjacent excavation squares and beyond would make a major contribution to the understanding of horizontal site integrity, site structure and activity area identification. Also, the establishment of an independent stone artefact conjoin dataset for these sites would contribute to understandings of taphonomic processes acting on different types of material. Unfortunately, stone artefacts are a relatively rare component of shell middens in southeast Queensland, reducing the potential of this line of enquiry in this region. The resolution of the valve-pairing from the Seven Mile Creek Mound would have been dramatically enhanced had all whole valves been plotted in three dimensions during excavation. This would have enabled precise assessment of the horizontal and vertical relationship between conjoining valve-pairs rather than minimum and maximum separations. Additional information may also be useful, such as the orientation, inclination and side-up of each valve (Hofman 1992).

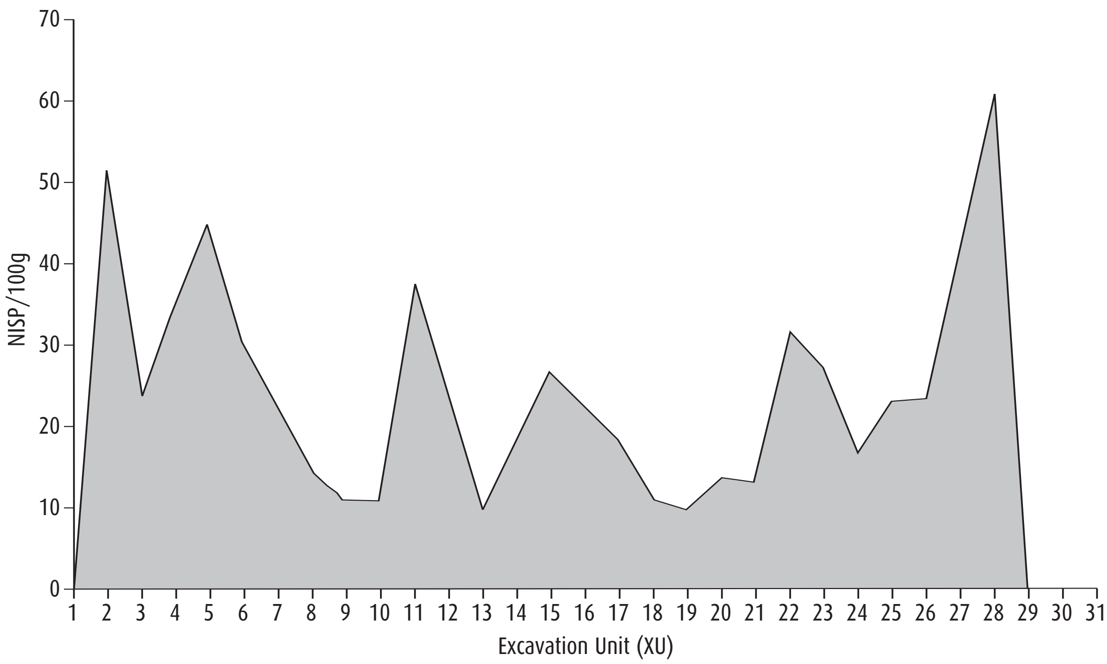

Figure 5.5 Fragmentation of *A. trapezia*, Seven Mile Creek Mound, Square A, expressed as the number of fragments per 100g of shell.

The techniques developed here could be applied to the examination of many excavated assemblages. Investigations of coastal sites have been conducted around the entire length of the Australian coastline (see Hall and McNiven 1999). With the possible exception of southwestern Australia, large shell middens have frequently been targetted for excavation. Bivalves suitable for conjoining are relatively common in these deposits, including *Donax deltoides*, *A. trapezia* and *A. granosa*. Valves of these taxa are robust and are frequently encountered as whole specimens in shell middens dating from the mid-Holocene. In some circumstances more fragile taxa may also be suitable, such as *Trichomya hirsutus* and *Mytilus* sp.

Summary

Articulated live-collected and excavated *A. trapezia* were used to derive reliable criteria for identifying unarticulated valve-pairs. These criteria were used as the basis of a systematic conjoin method which successfully identified valve-pairs among the unarticulated *A. trapezia* valves excavated from the Seven Mile Creek Mound. A subsequent blind test confirmed the reliability of the method but indicated that the amount of time devoted to assessing the conjoinability of individual valves was the single major determinant for maximising the number of valve-pairs identified. In the Seven Mile Creek Mound case study, the small distances which separate the majority of valve-pairs attest to the stratigraphic integrity of the site and may indicate episodic mound accumulation. In certain circumstances, bivalve conjoining may be a useful adjunct to conventional approaches to shell midden analyses, involving very basic characterisation of assemblage composition, with the potential to contribute an independent form of evidence to our understanding of site integrity (and resolution), discard patterns and periodicity of occupation. Shell conjoin analyses therefore provide one avenue to investigate differential deposition, dispersal and disarticulation patterns in bivalve assemblages.

The successful application of bivalve conjoining to the Seven Mile Creek Mound provides the basis for applying valve-pairing methods to other shell-dominated assemblages in the region as an adjunct to traditional approaches to the evaluation of site integrity. The techniques outlined in this chapter were applied to all excavated assemblages where whole *A. trapezia* valves were recovered. Results are presented in individual site chapters (Chapters 6–13).