52. Collection and analysis techniques for palaeoecological studies in coastal-deltaic settings

ROBERT A. GASTALDO

Many assumptions have been applied to the interpretation of Phanerophytic plant communities with relatively little actuo-palaeontological data and data analysis to support or refute them. Plant histology has not changed fundamentally since terrestrialization, and the decay or preservation of plant tissues has always been dependent upon the geochemical conditions prevailing in the sedimentary regime at the time of burial. For at least a century and a half it had been assumed by many workers that all plants, regardless of their bauplan or histological composition, had an essentially equal chance of becoming part of the plant-fossil record if conditions suitable for preservation were present. We now realize, based upon empirical data collected in modern depositional systems, that this is not true (e.g. Gastaldo 1988, 1992; Spicer 1989b). It is becoming clear that not every plant-life form in each vegetational tier of a habitat has the same probability of preservation (Burnham 1994), and that the taphonomic filters operating on those plant parts that are transferred from the biosphere to the lithosphere are facies-dependent (see Gastaldo 1989). Hence, it is becoming increasingly important to develop a contextual framework in Holocene depositional regimes that can be used for palaeoecological purposes.

Transitional settings of the coastal-deltaic regime are most commonly encountered in the stratigraphic record of the Phanerozoic. This is because they are geographically marginal marine and not only form during the culmination of highstand (maximum flooding and progradation of the coastline seaward) and lowstand systems tracts (maximum sea-level fall with shoreline pushed onto the shelf), but also during transgression when

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**Fig. 52.1.** Illustration depicting sampling techniques used to obtain actuo-palaeontological data in modern coastal-deltaic regimes.

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deposition occurs within incised valleys (formed within shelf or continental deposits during lowstand). Collection of macrobotanical and microbotanical samples in Holocene coastal-deltaic regimes involves sediment recovery in both aqueous and terrestrial sites utilizing a variety of sampling devices. There are both advantages and disadvantages to each method outlined in this chapter.

Rivers, bayous, bays and marginal marine settings

Techniques for sample collection in shallow water differ from those in deeper water (Fig. 52.1) and are dependent upon the hydrodynamics (river flow velocities and tidal regime) of the sampling site. Water-column samples for palynofacies (see Batten, Chapter 4) and palynological (see Traverse, Chapter 50) analyses are easily retrieved using a Van Dom-style water sampler. This device is composed of a one-litre transparent acrylic cylinder with rubber end plugs that are held within the cylinder by rubber tubing. Metal braided wires on the exterior of each end plug are attached to a trigger mechanism on top of the cylinder. When the cylinder is lowered to the desired sampling depth using a calibrated line, a brass weight (traveller or messenger) is sent to the release mechanism. The braided wires are disengaged, the rubber end plugs are released, and the cylinder is sealed. After recovery, the water sample can be removed through an outlet mounted on the side. Recovery of macrobotanical specimens in open water is more difficult because of specimen dilution within the water column. Although seining has been attempted (e.g. Scheiing & Pfeifferkorn 1984; personal observation), the results are unproductive, and in shallow water may reflect what has been re-entrained from the sediment–water interface. Inasmuch as plant part preservation is dependent upon the water chemistry, chemical characterization of the water column (and sediments) should include pH, Eh, dissolved O₂, CO₂, alkalinity, sulphide, nitrates, salinity and iron. Although sediment traps anchored at different depths have been useful for the collection of pollen, the dilution of macrobotanical remains within the water column generally precludes this approach.

Sample recovery from the sediment–water interface can be accomplished by one of several commercially available, bottom-sampling devices. Sampling dredges are designed for use on soft sediments (sand or silt) and are composed of two open boxes hinged at the centre. The device is lowered to the sediment–water interface while a simple trigger holds the sampler open. A scissor design closes the sampler, obtaining a sample that is then raised to the surface. With a spring-loaded cocking mechanism to malfunction, the BING Ekman-style box sampler overcomes some of the problems encountered with simple sampler dredges in river systems. This device is designed with two spring-loaded jaws that are held open during descent by braided wires attached to triggering device (similar to the Van Dom-sty sampler). Once the sampler is resting on the sediment–water interface, a messenger is dropped down the line to strike a release bar that causes the external coil spring to snap shut, trapping the sediment within. Overlapping cover plates loose hinged at the top of the device permit overflow water during descent and close on the ascent to prevent wash-out of sediment samples.

In shallow waters (<1.5 m), sediment–water interface samples can be recovered using a box corer, whereas shallow subsurface samples can be recovered using a large-diameter (6" - 15.5 cm) coring device (Burnham 1988). This device allows for a single sample to be taken rather than successive samples from within a small area. Its advantage over narrow diameter PVC pipe core (Scheiing & Pfeifferkorn 1984) is that the larger barrel diameter reduces sediment compression or distortion, but only allows for recovery to a depth of up to 0.45 m. Deeper subsurface samples must be recovered either using one of the various hand coring devices (see below), a piston corer or vibracorer.

Piston corers have been used primarily in lakes (Spicer 1981), although their use may be applicable in quiet-water bays and swamps (Cohen & Spackman 1980). A continuous, relatively undisturbed section of core can be recovered using the device. Limitations of this device, and modifications thereof, include a 5 cm core diameter and individual core segments of about 1 m (e.g. Moo et al. 1991). A new core barrel must be used for each subsequent segment, and it must be re-inserted into the same hole (a difficult task when covered water, although made easier with the use of plastic casing; see Wright 1980, 1991; Wright et al. 1984). Jackson (pers. comm. 1998) adheres to a strict rule of extruding core segments in the field between successive drives in order to assess what has been recovered and what to expect in the next drive. Although it has been estimated that piston cores can recover samples to depths of as much as 50 m, realistic recovery depths are limited to approximately >10 m in subaerial peat and subjacent incipient soils. Longer, individual core segments can be recovered using the compressed air sample modification of the Livingston sampler (Mackee 1958), but this apparatus was made obsolete with the development of the vibracorer.
Vibratory coring devices were originally designed for use on the Inner Continental Shelf and were used for decades from research vessels before these designs were modified to make them more portable for sediment recovery within barrier islands (Hoyt & Demarest 1981) and other coastal settings (e.g. Thompson et al. 1991). A 2- or 4-cycle, 4–5 horsepower, air-cooled, gasoline engine that is designed for use as a concrete vibrator is used as the power source for the coring system. This engine may be either a portable (enclosed within a steel frame for transport) or backpack model, and can be obtained from a number of manufacturers (see Appendix). The portable engine vibrator unit weighs 110 lb (50 kg) and is mounted on a swivel base; the backpack unit weighs approximately 30 lb (15 kg). A vibrator head with a flexible shaft (additional extension shafts are available) is attached to the engine, and the vibrator head is secured within a clamp (Fig. 52.2) that is...

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**Fig. 52.2.** Diagram for construction of clamping device used to secure the concrete-vibrator head to the aluminium coring tube used in vibracoring.
placed around a desired length of thin-walled (0.05" - 1.25 mm), 3" (7.5 cm) diameter aluminium-irrigation pipe. The coring procedure is easily accomplished by two individuals, whereas the length of the vibracore is limited only by the length of aluminium irrigation pipe and the composition of subsurface sediment.

Once the vibrator head is secured around the aluminium pipe near the top (it is recommended that the vibrator head be attached as high as possible), the pipe is raised to an erect position, the engine started, and the throttle increased to where the engine is supplying approximately 10 000 vibrations per minute. The vibrations are passed along to the pipe. A standing wave is established allowing the pipe to slide into the ground because the sediment adjacent to the wall of the pipe becomes thixotropic. The pore water within the sediment acts as a lubricant, allowing the core to penetrate. Eventually, enough friction develops (or more cohesive clay-bearing sediment is encountered) that stops further penetration. Normal penetration is 5 to 8 m, although cores exceeding 11 m have been recovered. Once the coring is completed, the clamp is moved to the sediment interface, the excess pipe is cut free, and orientation to north is marked on the side of the core barrel (allowing for ease in determining the split orientation when evaluating plant part deposition relative to water flow direction). A metre-stick is lowered into the core barrel to determine the difference between ground level and the core top, providing some estimate of compaction (usually less than 0.5 m in 10 m depending upon sediment composition). The core barrel is filled with water and capped with an expandable plug (available from any plumbing supply store), preventing the loss of sediment during extraction. A 10-13 ft (3-4 m) aluminium tripod is placed over the core barrel, and a pulley device (1.5 or 2 ton capacity come-along or winch) is attached around the core barrel; the pipe is manually extracted. When fully extracted, the core is laid down and the bottom capped with a plastic end cap. North orientation is marked along the entire length of the core barrel. It is then cut into 1 m length sections using a hacksaw, capped and transported to a processing area. Here, the aluminium pipe is cut on opposite sides using a carbide-tipped, hand-held circular saw modified with a cutting guide (the depth of which allows the blade to penetrate 2 mm below the pipe wall). The core is split with monofilament line (a sharp knife may be used to cut matted rhizomes and saturated wood) and opened along the cut. One side of the core is photographed (Fig. 52.3) and archived, while the other side is described and sampled. On-site Eh and pH measurements can be taken using meter probes inserted into the split core sediments (Gastaldo & Huc 1992), and additior pore-water chemistry, as well as total organic carbon (TOC), Rock Eval, and sediment analysis can be performed in the laboratory. Disadvantages to this technique may include 'rodding' (occasionally when a compacted clay plug gets stuck in the core barrel, preventing complete recovery at depth) compaction (dependent upon the physical nature of the cored sediments), and core loss upon extraction (when sandy sediments are oversaturated; e.g. quick sand).

The portable system has been used for sampling in deep water from boats or barges as well as terrestrial settings (Gastaldo & Huc 1992); the backpack system has been equally successful (Gastaldo et al. 1996) in all these settings. The advantages of size, weight and transport (partic...
larly over rough terrain) make the backpack system preferable. Hoyt & Demarest (1981) note several advantages of the vibracore system over most other coring systems used in similar settings (including terrestrial elastic and peat; see below and Fig. 52:3). Equipment cost is affordable (approximately $1500.00) and the relatively simple operation uses all hand-operated equipment that is easily transported. Cores can be taken virtually anywhere on land and in moderately deep waters (using modified boats or pontoon craft), and sediment cores are virtually undisturbed except for a 1–2 mm zone adjacent to the core pipe. The coring device has been used successfully in fine to moderately coarse sediments (including pebble conglomerates, personal observation). It must be noted that the system is not perfect. Core sites are limited to where access to water-saturated sediment is available, although vibracores have been extracted from floodplains in Coeur Alene, Idaho, by saturating the ground above the water table prior to coring. The depth of penetration is limited by subsurface sediment composition (plastic clays, consolidated sediments, and medium-to-coarse, well-sorted sands are very difficult to impossible to penetrate). Additionally, vibracores can get a compact plug (sediment, wood, or root) stuck in the end virtually at any depth, which prohibits collection of sediment when the coring tube is introduced through the sediment.

**Terrestrial environments**

Sampling protocols for collection of ecological data in various ecosystems are well established (e.g. Kent & Coker 1992) and have been used in actuo-paleoentological investigations that address litter production, accumulation, and representation (e.g. Burnham 1994). These techniques include: sampling quadrats, and the concepts of minimal area, species-area curves, and vegetation pattern within quadrats; species abundance as measured either through subjective (estimate using a Domin or Braun-Blanquet scale) or objective (presence/absence, density counts, frequency and biomass) methods; and line-intercept, transect, griddel, or plotless sampling methods; leaf and pollen traps (see Moore et al. 1991).

Subsurface sampling has generally been restricted to what has been recoverable using hand-coring devices of limited capacity (although vibracores overcome this problem, providing a higher fidelity subsurface record). These samplers are the modified Hiller (Thomas 1964), Eijkkelkamp and Russian peat (Jowsey 1966) samplers, costing the same or more than a vibracore (see Appendix). With the use of extension rods, these devices can provide subsurface samples to depths >10 m.

The Hiller sampler, and modifications thereof, is a chamber sampler fitted with an auger, requiring it to be twisted clockwise as it penetrates the sediment. By changing the motion to a counter-clockwise direction once the depth of sampling is reached, the inner rotating flanged chamber opens and scores a sample from the adjacent sediment. The disadvantages of this apparatus are noted by Moore et al. (1991) to include: contamination due to entrapment of roots and other subsurface plant detritus during descent; not only is the sample disturbed by the auger head, but material beneath the sample to a depth of 10–20 cm is disrupted; and the intact core cannot be removed in its entirety from the sampling chamber.

The Russian peat corer does not have an auger head to disturb the sediment during emplacement and, hence, must be pushed vertically into peat or saturated, soft sediment substrates. The sampler consists of a half-circular tube with a centrally hinged main blade. Upon emplacement, the handle is turned 180° cutting out a half-cylinder of adjacent sediment. The blade remains stationary during sampling and is the only part that is in contact with the sediment to be sampled during descent. Moore et al. (1991) note that the advantages of this device include: a simple design strategy that limits contamination during emplacement; minimal sediment disturbance; and the ability to view and collect a full core exposure. Peats can also be sampled by excavation and the removal of monoliths, which is especially useful in tundra and alpine settings (Jackson, pers. comm. 1998), using a 10 cm piston corer with serrations on the core barrel (see Wright et al. 1984).

**Data retrieval**

Holocene macrobotanical remains collected either at the soil–air or sediment–water interface or from the subsurface should be stored in ethanol or a 1:1:1 mixture of glycol, ethanol and water to prevent degradation, and preferably refrigerated. A dispersant is usually needed to disaggregate the organic remains from the siliciclastic matrix, and the residue can be gently wet-sieved using a 250 μm (2 Φ) screen to recover fruits and seeds. Clastics can be removed from fruits and seeds using a 30% hydrofluoric acid (HF) bath for 24 h, followed by 30 minutes in 30% hydrochloric acid (HCl).

**Data analysis**

Plant litter recovered from marginal marine, coastal plain, and deltaic settings can be analysed using established ecological procedures with the caveat that the investigator recognize whether or not the
accumulation is autochthonous, paraautochthonous, or allochthonous. There are limitations in translating many of these procedures to fossil assemblages because of limited outcrop exposures, sample size, preservational quality and the lack of a sedimentologic and taphonomic framework.

In autochthonous assemblages where plants are preserved erect (in situ), as forest-floor litters or peat (lignite/coal), it may be possible to determine the plant-life form, although presently accepted life-form categories (Da Rietz or Raunkiaer) may not be applicable because of the characteristics upon which some are based. Additionally, it may be possible to: ascertain physiognomy; calculate density, spacing pattern (e.g. DiMichele & Demars 1987), and frequency in standing assemblages (Mosbrugger et al. 1994); determine basal area, girth and diameter in standing assemblages (e.g. Mosbrugger et al. 1994); estimate cover and biomass production; and map vegetation (application of Burnham (1994) to forest-floor litters). If exposure is extensive, gradient analysis (a variety of methods to simply represent a continuum), ordination (such as correspondence analysis or reciprocal averaging these techniques can also be applied to paraautochthonous assemblages), Spicer & Hill (1979), detrended correspondence analysis (DiMichele et al. 1991), and non-metric multi-dimensional scaling (MDS) can be applied (Phillips & DiMichele 1988).

In all assemblage types it is possible to determine diversity indices, although Kent & Coker (1992) note that confusion exists over the meaning of the term, the methods for measuring and assessing diversity, and interpretations of different diversity levels. Two types of species diversity are recognized generally along a gradient – $\alpha$ diversity is the number of species within a collection, whereas $\beta$ diversity is the difference in species diversity between collections (and sometimes termed habitat diversity). The most commonly employed diversity indices that are based on both species richness and equitability (evenness of species abundance) are the Shannon–Wiener (e.g. DiMichele et al. 1991), McIntosh’s, and Simpson Indices, whereas dominance-diversity curves are based upon the plot of the log-transformation of proportional species abundance in a sample against their rank from most to least abundant. The form of this line is then used to describe the evenness of species distribution and relative species dominance in the assemblage. In compression assemblages it has been common to either (1) count hundreds of leaves per site, each identified to species, with relative abundance calculated on the proportion of specimens per taxon, or (2) treat each block of rock as a separate quadrat and score any taxon as present in that quadrat (Pfefferkorn et al. 1975; Wing & DiMichele 1995). Comparisons of these two methods of estimating species abundance have shown that both methods estimate similar species richness and rank-order abundance (e.g. DiMichele et al. 1991). Not only should extreme care be taken when comparing data from autochthonous/paraautochthonous assemblages with allochthonous assemblages due to the inherent bias towards sampling of riparian elements in these latter accumulations, but it has been demonstrated that forest-floor litters from forests inhabiting different climate zones should be treated with a climatic filter when estimating plant diversity in the past (Burnham 1993).

The application of parametric statistical analyses to these data require that there is an underlying assumption that the data are normal in distribution. Quite often, particularly in fossil assemblages, there is no way to test for normality. Hence, the application of non-parametric statistical tests (those that make no such assumptions about the distribution of the background population or sample) provide a suitable alternative (see Shi 1993 for a review).

When contemporaneous or coeval modern or fossil assemblages are being compared, many different measures exist to assess sample similarity (the degree to which species composition of samples matches is alike) or dissimilarity (the degree to which two samples differ). Some techniques are qualitative (e.g. presence/absence), while others are quantitative (e.g. abundance data). The Jaccard and Sorenson (Burnham 1993) coefficients are generally applied to presence/absence data (but see Archer & Maples 1987), whereas the Czekanowski coefficient (Pyror 1996) and coefficient of squared Euclidean distance may be applied to either type of data. There are many other coefficients that have been used (see Prentice 1980 for review). The resultant matrix of similarity or dissimilarity coefficients may be further analysed by cluster analysis (Kovach 1989) to determine underlying patterns within the data (Gastaldo et al. 1996).