ANCIENT WATER MANAGEMENT AND LANDSCAPE TRANSFORMATION AT SEBATU, BALI[1]

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> "... the *pedandas* [high priests] make the "pure" holy water (*tirta*) used in such profusion in the ritual that the Balinese have come to call their religion *agama tirta*, the 'science of the holy water' " (Covarrubias 1937:298).

ABSTRACT

The island of Bali has fascinated cultural anthropologists for decades. The rich yet composed investment in performance ritual by the Balinese continues to unify and define their identity. In spite of the considerable time spent in attempting to know Balinese customs and sociopolitical organisation, less is understood about their ancient past and the importance of their economy. By carefully mapping and subsurface coring one sizable, present-day temple complex and associated rice paddy fields, a picture of an evolving political economy within a highly engineered environment is presented.

SETTING AND BACKGROUND

Drawing on Lansing's study of water temples and the political economy of Bali (Lansing 1987, 1991; Lansing and Kremer 1993), a pilot archaeological program was initiated to reveal the rate and process by which the landscape was altered. The presumed center for early experiments in statecraft is the greater Tampaksiring-Pejeng area, Gianyar Province, in south-central Bali (Figure 1). Several sizable and complex ruins dating from the late 9th to the mid-11th centuries occupy the incised banks of three southward-flowing, parallel-running rivers, the Oos, the Petanu, and the Pakerisan (Bernet Kempers 1991) (Figure 2). Although these rivers are deeply cut into the ignimbrite volcanics comprising much of this zone, there are places where topographic relief is gentler than most other areas of highly dissected interior Bali. Further, the welling of springs at sites located away from these rivers, but within the ancient valleys, established small pockets of swamp-like conditions that may have drawn early horticulturalists to these settings. An elevated water-table in surrounding areas permitted the establishment of long-term sedentism, in part associated with the rich natural biota found in swamp settings, and provided patches of level ground suitable for early broadcasted rice varieties. Bali receives a generous rainfall, over 1500 mm annually, in the Tampaksiring-Pejeng zone. Nevertheless, it is a seasonal precipitation making formal irrigation paramount for a successful rice economy today.

Here we summarise the results of recent ethnoarchaeological and archaeological investigations intended to illuminate why Bali did not develop greater centralised political and economic organisation when compared to other experiments in early statecraft. The focus of our exploration is the water temple complex and its intricate decision-making apparatus that developed in the context of this highly dissected and volcanically volatile tropical environment. Our study of a temple system associated with the greater community of Sebatu in the Tampaksiring-Pejeng area suggests a slow, incremental development of the landscape from forest management adaptations to highly intensive rice paddy terracing over a period of at least 500 years. The technologies permitting this harnessing of water and soil are coincident with a developing political economy, one different from those noted elsewhere.

Together with a careful program of mapping, subsurface coring operations within the temple and associated fields enabled environmental, historic, and prehistoric reconstructions of the Sebatu landscape. The unexpectedly high

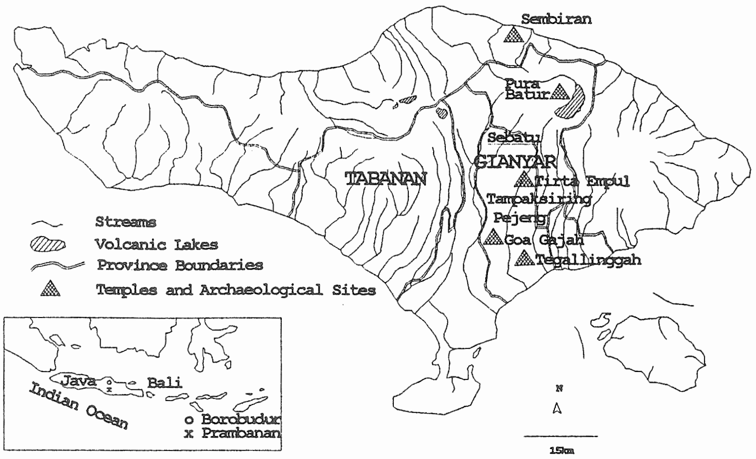

Figure 1: The island of Bali, showing sites mentioned in the text.

rates of siltation in the adjacent agricultural fields accent the dynamic nature of the steeply incised landscape and the deliberate capture of sediment from eroding hillsides. Behind both sizable dams and diminutive rice terraces are deep depositional layers that are (and long have been) sufficiently fertile to sustain Bali's agricultural wealth.

Further, the cooperative relationships among farmers linked both physically and socially by the water temple network results in a dispersed community settlement pattern reflective of the unique topography of Bali. This dispersed land-use pattern mimics the original tropical ecosystem present before the advent of intensive paddy cultivation, with monocropped rice terraces being the means by which resources were concentrated within the otherwise diverse and widely dispersed species distributions of the most ancient tropical Balinese landscape.

AGRICULTURAL AND POLITICAL DEVELOPMENT

Archaeological evidence for the earliest domesticated rice (*Oryza sativa*) on Bali comes from phytoliths found in the Pacung excavations (Ardika 1991:12-15, 178-181; Bellwood *et al.* 1992) near the earlier Sembiran excavations on the island's north shore (Ardika and Bellwood 1991) (Figure 1). These rice indicators suggest that the crop was grown on the northeastern coastal plain by at least 2000 years ago. With only half the annual rainfall of the Tampaksiring-Pejeng area and few perennial streams (McTaggart 1988), the narrow coastal zone could have rapidly become overcrowded given successful returns in rice and related plant yields. Driven by an expanding population, coupled with innovations in the suite of crop varieties and cropping techniques, Early Metal Phase chiefdoms (*c.* AD 200-800) (Bellwood 1997) extended over the island with a well-defined material culture characterised in the Tampaksiring-Pejeng zone by stone sarcophagi and a range of bronze artifacts (Ardika 1987; Bernet Kempers 1991; Soejono 1977; Sutaba 1980).

With time, the Tampaksiring-Pejeng zone probably supported more people than most other areas at a comparable pre-state level on Bali. By late in the Early Metal Phase, experiments in formal irrigation were likely – especially in those pockets within such areas as Tampaksiring-Pejeng where potentially irrigable land could be modified easily without major landscaping investments. Intensification efforts on the landscape (e.g., terracing) were probably initiated at this time. As Scarborough has argued elsewhere (1993, 1998) and as we shall propose here, these were slow, accretional developments leading to greater levels of sociopolitical organisation and social complexity.

By the advent of the Late Metal Phase (AD 800+), intensive landscape alterations associated with rice terracing had begun. Political centralisation and the focused concentration of resources at a few locations are suggested by the first appearance of monumental architecture such as rock-cut *candis* (temples, shrines) and cloister buildings (Schoenfelder 2000). This is complemented by early inscriptional evidence indicating that irrigation tunnel builders – *undagi pangarung* – constructed tunnels to move water through Bali's prohibitively steep and dissected ridge and valley contours (Goris 1954:55, 330; also, Ardika and Beratha 1996:23, 49). For the first time irrigated waters could be tapped from upstream sources, routed through the flanking ridges, and allowed to moisten other ridge tops positioned at slightly lower absolute elevations but impossible to irrigate without tunnel technology.

Given this new technology and an increasingly intensive use of the landscape, why is it that Bali did not continue the process of political and economic centralisation? By the 12th century consequential building was on the wane, though a rich iconographic and epigraphic record continued (Bernet Kempers 1991; Goris 1954; Stutterheim 1935). Unlike neighbouring Central Java with its extreme investments in monumental architecture, as characterised by Borobudur

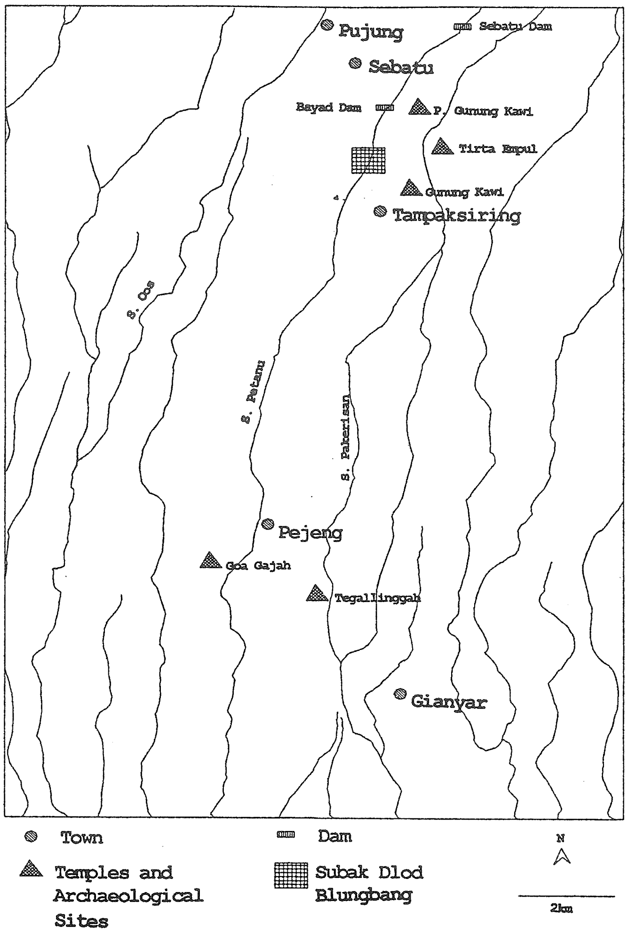

Figure 2: Tampaksiring-Pejeng area, Gianyar Province, showing sites mentioned in the text.

and Prambanan (9th and 10th centuries) (Dumarcay 1986), Bali did not have the level land area and perhaps the initial fertility of soils to sustain focused resource exploitation in a similar manner. These Javanese sites were several orders of magnitude more grand than Gunung Kawi, the largest of the Balinese 11th-century *candi*s or temple edifices (Bernet Kempers 1991; Dumarcay 1986).

In Bali, in contrast to Java (Bentley 1986; Miksic 1996, n.d.), the basic form of the theater state (*negara*) survived into the 20th century. The central mystery of the Balinese "theatre states" is why the first large kingdoms were succeeded by a plurality of smaller competing principalities; "dozens of independent, semi-independent and quarter-independent rulers" (Geertz 1980:19). Schoenfelder (2000) has argued that the weakness of the Balinese *negara* was partly a consequence of interaction between a coexisting alternative hierarchical system based on economic and ritual ties linking water allocation and land use to water temple networks.

THE ENGINEERED LANDSCAPE OF BALI

We believe that self-organised rice field cooperatives, or *subak*, played a crucial role in the evolution of the Balinese landscape and political economy. Present-day *subak* consist of about 50-400 farmers who usually obtain water from a common water source – a spring, a dam or a specific branch of a major irrigation channel. Under a leader elected from within their ranks, *subak* members meet regularly to arrange cropping schedules, apportion water, and assign communal labour tasks (Barth 1993:72; Geertz 1980; Lansing 1987; Liefrinck 1969; Schoenfelder 2000). We do not know when the *subak* division evolved (see Ardika 1994; Setiawan 1995; Suadnya 1990) [the term "kasuwakan" (*subak*) appears in the inscriptions by the 11th century though we cannot be certain of the exact meaning of the term at that date], but today it represents a semiautonomous sociopolitical and socioeconomic unit responsible for group decision-making about the irrigated landscape. The *subak* coordinates the myriad of microlocal tasks timed and performed on each active rice paddy, nearly every day of the year.

Subak organisation functions in part to provide adequate water allocations to specific paddies at specified times while controlling for the outbreak of insect infestations that spread rapidly from one adjacent field to another. Lansing (1991) suggests that *subak* organisations are engaged in an ongoing set of negotiations with the natural world. Although uninterrupted cropping of rice would produce larger harvests, for ecological reasons this is not possible. Water is a finite resource while pests are always available and troublesome. Through a system of water temples acting as "information nodes" the Balinese equitably coordinate the needs of the farmer and the food demands of society.

Although much remains conjecture, we posit that Bali was able to intensify its engineered landscape because, after an initial period of early centralisation associated with monumental construction, it soon, and thereafter, was ruled by a less centralised and more contentious set of principalities. These political divisions were grounded in the abundance of successful rice yields and the concentration of resources made available to the élite managers of society. Balinese *negara* or principalities were decentralised political units that developed in concert with the increasingly complex set of economic decisions required to engineer the agricultural landscape. Because the acceptable decisions needed to manage and produce necessary yields for a growing population became unwieldy, a locally coordinated system influenced by Hinduism and water symbolism evolved.

With an accelerating need for more food, associated with a greater pool of labourers, Balinese rulers increasingly relinquished decision-making control over certain sectors of the political economy to the evolving *subak*. Although the centralising elements leading to 10th- and 11th-century sites like Goa Gajah, Tirta Empul and Gunung Kawi were a necessary impetus for stimulating a level of early resource control and experimentation in rice production, Lansing's models show that over time a process of self-organisation could have enabled the *subak* to sustain high levels of production with minimal control by the rajahs.

A more classic hegemonic state system – even a less "typical" experiment in statecraft like the 9th-century Central Javanese state with its tremendous concentration of resources as manifest in monumental architecture – would have rapidly forced the internal collapse of the ancient Balinese political economy. In our model, it is precisely the inability of the early Balinese kings to command the resources necessary to control power relationships – and their incapacity to establish highly centralised nodes or "cities" (Miksic 1996) – that permitted institutional development to proceed on a course better suited to the dispersed resource base. The early development of the *subak* system and the water resource interdependency that it requires best mimic the tropical ecosystem of which early Bali was a well-defined example (see Scarborough 1998).

SEBATU

In an attempt to investigate the processes outlined above, we selected the ancient but active water temple and rice paddy system (*sawah*) of Sebatu, Gianyar, south-central Bali, for study (Figures 1 and 2). Located less than 3 km northwest of both Gunung Kawi and Tirta Empul, the water temple of Pura Gunung Kawi Sebatu is positioned near a small tributary of the Petanu River. The location was chosen because of its proximity to the 11th-century monuments and because it was a mid-sized temple and field complex perhaps less disturbed than the larger sites commonly receiving more attention. Further, the *Reconnaissance Soil Map for the Bali Irrigation Project* (1985) indicates that the Sebatu area is one of the most attractive zones in the entire Gianyar Province for both rice production and dry farming, even more so than neighbouring Tampaksiring or Pejeng. Sebatu's water temple setting and discrete spatial limits – as defined by the precipitous valley walls – made mapping much of the site area less difficult, though the ancient area under cultivation would have been less than that apparent at some other sites. This latter condition might argue for its colonisation at a slightly later moment than that at Tirta Empul. Tirta Empul is associated with the Tampaksiring-Pejeng area's most elaborate spring and fountain system and with slightly more level ground than found in other valley settings, conditions perhaps conducive to early experiments in irrigation.

Just as significant to our selection process was our ability to gain access to the temple grounds for both mapping and coring. Because the temple was an active one, specific questions about the immediate history of the temple and the modification of the *sawah* were addressed. Although the temple priests were knowledgeable, they were most keen to learn our interpretations. References to the history of the temple were said to have been recorded on a *lontar* palm manuscript, which was taken from them during the Dutch occupation of the island.

A map of the area was drafted to establish a baseline for all subsequent work in the temple complex (Figures 3, 4, and 5). Given the rich ethnographic context in which we were

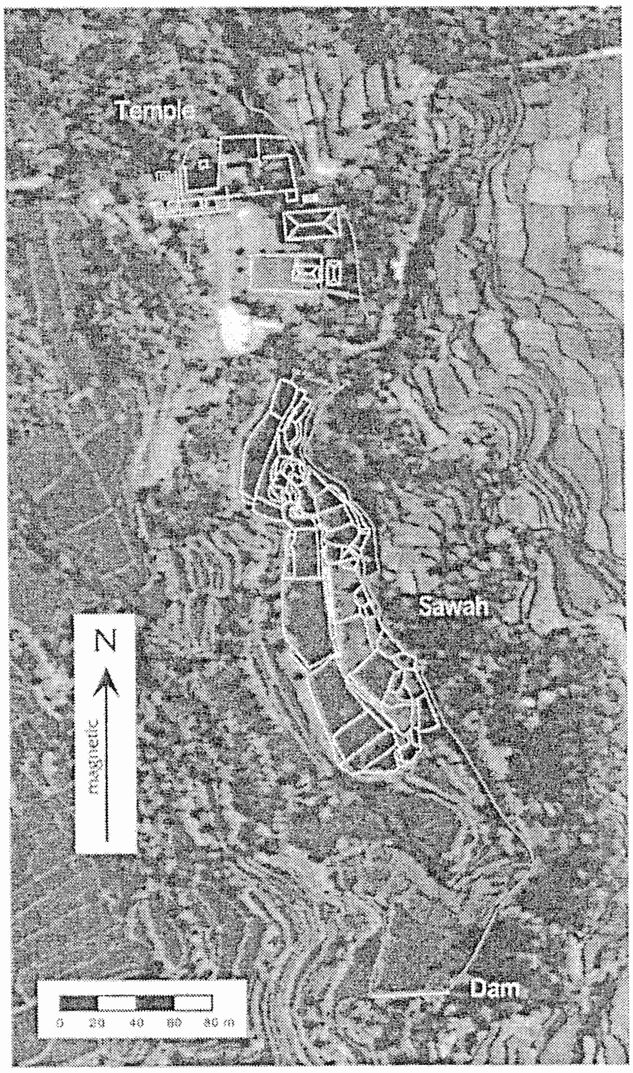

Figure 3: Aerial photograph of the Pura Gunung Kawi area, with recent map of the water temple and adjacent rice paddies superimposed.

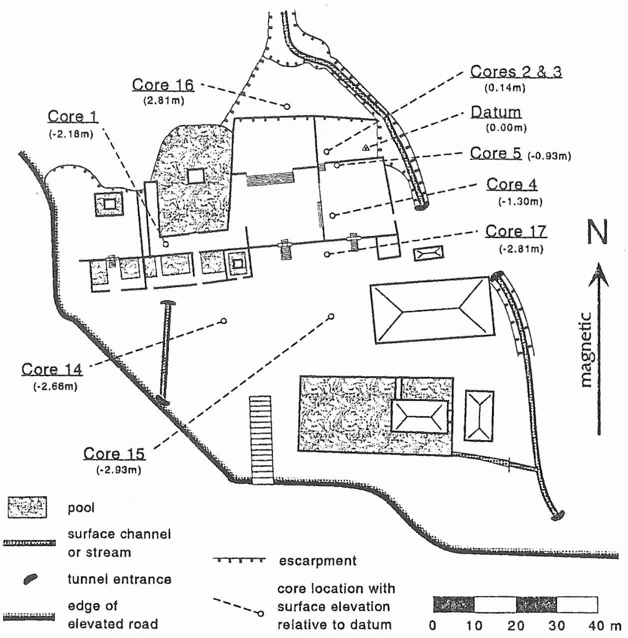

Figure 4: Map of water temple (Pura Gunung Kawi Sebatu), showing soil core sample locations.

placed, a good interpretive understanding of the mapped features was possible. This strengthened our archaeological assessments based on the subsurface coring program and improved our ability to identify both cultural and natural processes influencing the relocation of water.

The map was designed to capture variability in the carefully engineered landscape, especially those nuanced contours affecting the movement of water. In terms of water access and purity, four divisions were made, located in descending elevational order: (1) an inner temple zone defined by the spring source, (2) a middle temple zone, (3) the outer temple courtyard and (4) the *sawah* or rice paddies.

The inner temple zone contained the sacred shrines and the most pure and holy of waters; it also occupies some of the highest ground at the site. The principal feature was the springhead tank defined by a sunken rectangular wall containing the gently bubbling spring waters. At least three terraces defined the remainder of the inner zone with the back wall of the largest set of shrines cut three vertical meters from the steeply rising valley slope. Nevertheless, behind and above this north wall was an elevated and level space that may have been used to agricultural ends in the past. It was from this immediate and adjacent setting that our core 16 was retrieved. In addition to core 16, cores 2, 3, 4, and 5 were retrieved from the central east and northeastern side of the inner temple revealing bedrock at approximately 3 m below the surface and suggesting the underlying slope of this buried ancient surface.

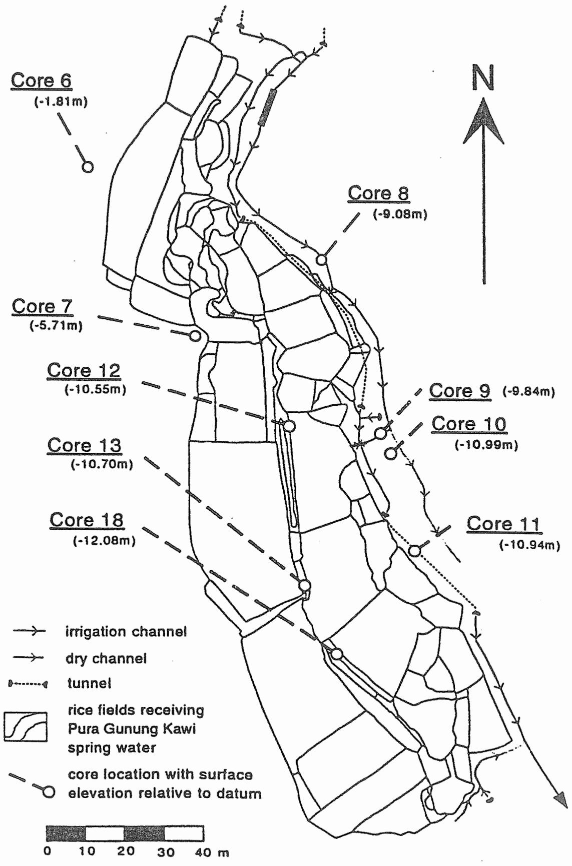

Figure 5: Sawah *(rice paddy) map, showing soil core sample locations.*

The middle temple zone was identified by a partitioned area containing the bathing pools at Sebatu as well as access to further partitioned holy water. It occupied a narrow rectangular area running east-west and extending along the west central portion of the temple grounds. The springhead tank was immediately above this zone separated by a walkway under which spring waters were directed to the baths. Core 1 was taken from the walkway and revealed moving water at 30 cm; the core descended uninterrupted to a maximum depth of 5 m through sediments suggestive of rich swamp-like peat and a spring depression as partially defined by the elevated bedrock (3 m below surface) noted above to the east in the inner temple zone. Water issued from spouts placed in the sunken north sidewalls of the bathing area.

The outer courtyard was a sizable zone that was significantly modified in the 1960s to accommodate a flanking road. An open rectilinear courtyard defined the entrance to the temple grounds – grounds accessed by a wide stairway down from the elevated road. At the southern and eastern margins of the courtyard and immediately below the road was a sizable, cement-lined reflecting pool. Water appears to be channeled by underground pipes from the inner and middle temple zone to sunken spouts pouring into the recessed tank. This feature represents a significant modification of the temple grounds in the last 30 years and provides a cautionary note to the less than ancient antiquity of portions of a landscape as dynamic as that of Bali. It is important to note that cores 14, 15 and 17 from within the courtyard revealed very wet sediment within 3 m. The bubbling springhead within the inner temple is the only area permitted to pond water derived immediately from the subterranean source. It is likely that other areas in the outer courtyard are affected by spring activity, but these zones are capped so as to direct water use.

Waters from the principal spring tank in the inner temple zone as well as the likely capped sources in the courtyard move into the reflecting pool and out a well-defined concrete flume of recent origin to join a small natural stream. This water then flows under the road spanning this upper valley area. Another channel originates at the bathing pools and passes under the roadway at a location permitting the irrigation of elevated paddies on the western side of the mapped *sawah* zone.

THE *SAWAH* MAP

The 0.89 ha of *sawah* mapped is watered from and contiguous with the water temple zone; this permits an assessment of the symbolic as well as the functional relationship between the two (Figures 3 and 5). Although only a small segment of the field system is surveyed (most of the water from the temple spring is not used by the farmers of Sebatu, but by villages downstream), the area selected reveals the intricacies of the agricultural system and the number and variety of decisions required to crop the Balinese landscape. Precise control over water is the key to the *sawah* system – water manipulation resulting in an artificial pond ecology, not just moisture to the rice plant's roots (Lansing 1995:87-89).

Once water entered the rice fields three conduits directed water to: (1) a diminutive set of paddies referred to as a *tempek* – contiguous paddies controlled by several farmers and watered from a common source – positioned on the western side of the incised valley floor and supplied exclusively by the limited temple waters issuing above the natural stream, (2) a sequence of channels and tunnels carrying the bulk of the spring water away from the area altogether and to the 31 ha of *sawah* maintained by Subak Dlod Blungbang 4 km to the south, and (3) the highest canal carved into the outcropping ignimbrite along the eastern edge of the valley which was the source for the water to the remainder of the fields mapped.

Consultation with local tunnel engineers indicates that considerable modification of the paddy system has occurred in recent memory. An earthen dam once spanned the area between core 11 and core 13, though its size and impact on the present distribution of fields is difficult to assess. Dams and weirs across the frequently steep gradients on Bali functioned to slow and divert potential irrigation waters – an adaptation of antiquity as suggested immediately north of the 10th-century monuments at the small rock-cut *candi* of Tegallinggah (Bernet Kempers 1991:161). Furthermore, Ardika (1987:58) notes that, according to the inscription of Manukaya dated to AD 960, the spring of Tirta Empul at Tampaksiring was dammed by Sang Ratu Cri Chandrabhayasingha Warmmadewa to avoid annual flooding (also see Goris 1954:75). However, the quantity of sediment over time carried by these waterways is also significant, much of it deposited behind the shallow dams. Given the depth of our coring operation – core 12 descended to nearly a 5 m depth, for example – it is likely that much of the matrix defining the rich planting surfaces over time was derived by capturing the clays and silts in this manner, with the dams subsequently removed when the gradient was significantly altered.

Mapping the margins along the valley's flanks was difficult because of the vegetation impeding visibility and the steepness of the slope. Most of this less favourable land was terraced, but in fallow or covered by tree crops – though some was formally irrigated and in rice production immediately outside our mapped zone. The water responsible for irrigating these slopes was derived from another water source.

The west flank of the valley was much steeper than the east and was formed by cutting the slope back to accommodate narrow terrace surfaces. The soils were not as productive as those elsewhere, given the difficulties associated with water access and the proximity of the regolith to the surface, although temporary field houses and the organic detritus in their wake as well as some deliberate mulching have increased their fertility. Cores 6 and 7, taken from these upper terraced fields, reached highly compacted matrices within 2 m; these soils were very ancient and appear to have had the original mantle of soil removed.

The eastern lower margins of the valley floor were partially built up by the sediment accumulation associated with the dam noted above and probably by the relocation of soil from the lower and less precipitously terraced ridge on this side of the valley. Cores 8, 9, 10, and 11 were placed in fields along this margin between the upper easternmost canal and the rapidly descending lower more westerly course that ultimately exited the *sawah* via an underground tunnel. It should be noted that at the approximate location at which the water from the lower conduit disappeared under the present field system, three additional tunnels were discovered. Two of them, perhaps related to the earlier position of the earthen dam, were abandoned. A third may be a switching locality allowing water into another set of fields via a tunnel running underneath the eastern flanking ridge away from the present southeastern flow.

Cores 12, 13, and 18 were located on a wide north-south-trending berm bisecting the lower half of the *sawah*. Core 12 descended nearly 5 m, though the last meter was too wet to process. Cores 13 and 18 probably descended to a comparable depth, but we could not determine their penetration with accuracy because mechanical difficulties interceded. The soils and sediments from these cores suggest a deep depositional history associated with degraded sediments eroding from above the water temple area.

The intricacies of the water system at Sebatu are impressive, especially when only an area of less than one hectare is examined. Bali is a highly engineered landscape and when this degree of construction and maintenance is extrapolated for most of the island, a clear picture of the micromanagement necessary begins to come into focus.

CORE DATA

The analyses associated with the matrices recovered from our coring efforts are preliminary; nevertheless, the sediment history revealed by the coring effort provides a narrowly opened window into the rate and process by which the ancient Balinese intensified their agricultural production while developing a dispersed land-use strategy coordinated by the economic underpinnings of the water temples. James Nicholas at the University of Cincinnati is responsible for assessing the soils and sediments. Dr. Simon Haberle at the Australian National University generously provided his time in evaluating two of the cores for ancient pollen, while Dr. Lisa Kealhofer at the College of William and Mary analyzed one of these latter cores for phytoliths. Chronometric dating was conducted by Beta Analytic Inc. It is important to emphasize that much more information is necessary to fully support or negate the forwarded thesis. Only formal excavation of the cored zones will adequately test the hypotheses. Until that is possible, the following data are presented as pilot information on which subsequent field studies may build.

The dry-land coring was conducted in 18 separate contexts across the Sebatu water temple and *sawah* area. Each context was selected to elucidate the sediment history of the zone. To date, three cores have been examined from above and within the inner courtyard, another two from the outer courtyard, and four others from within the *sawah* fields. Seven Accelerator Mass Spectrometry (AMS) dates were obtained from varying contexts. Only core 16 is presented with a tabular reconstruction of its stratigraphy. Because of poor chronological control and an absence of botanical indicators, with the exception of cores 14 and 17, the other cores inventoried in this study are not detailed here. What is most apparent from the variety of data retrieved is that the temple setting is a dynamic environment reflective of the steepness of the terrain, the active volcanism on the island, and the level of human industry in inducing alterations.

All surface elevations were tied to a standard topographic datum located in the upper northeastern section of the water temple, but all core measurements relate to an internal depth below the surface point (0.0 cm) probed at that particular locality. This is not as straightforward as it might seem. The coring device provides a potential penetration depth of nearly 5 m. Nevertheless, the device descends in segments of 90 cm, with significant vertical compaction of moist and loose sediments. This results in core segments that descend the full 90 cm but contain actual sediment segments sometimes significantly less lengthy. The coring depths provided in the text are computed by assuming that 90 cm of sediment was removed from a core location, even though the soil subsequently examined was compressed. No additional attempt is made to extrapolate the degree of compression when identifying the depth of a specific sample within the core segment. Such sample provenience depth was determined by adding the number of 90 cm segments above the specific sample spot and appending the compressed sediment depth within the final core segment to the total.

The oldest date, 17,620±50 BP, comes from the basal reaches of core 17 at 295 cm below surface datum (BSD) – in the outer courtyard – and appears associated with a swamp-like peat environment. Unfortunately, the pollen and spores retrieved from this context are too limited in numbers and too weathered in appearance to be helpful. In spite of the poor preservation, the earliest evidence from the Sebatu soils and sediments supports the presence of a swamp-like setting. Importantly, no indicators exist for the presence of humans in the vicinity of Sebatu at this early date. Nevertheless, that the setting was a swamp may suggest its initial attraction to early sedentists.

Our next datable context comes from core 16 (Table 1) – immediately behind (north) and above the inner courtyard – at 275 cm BSD and yet, in absolute terms, 582 cm higher than the swamp date of core 17 located 70 m to the south. A calibrated date of AD 1445±25 from a wood fragment was recorded for this core 16 point. It remains difficult to determine precisely the environmental history of the core, but soon after this date the incidence of carbonised particles,

Table 1: Core 16 stratigraphy

Core & seg	cm w/in core seg	Munsell reading	Texture	Soil structure	Organic inclusions	C-14 data	Pollen data	Phytolith data	Other descriptions
16a.1	0-3	2/1 10 YR	sandy clay	blocky	highly organic; fibrous				charcoal
	3-13	3/2 7.5 YR	sandy clay	subangular blocky	fibrous organic material and roots				grit and hallophane crystals
*	13-22	3/4 7.5 YR	clay loam	subangular blocky	less frequent root or root hairs		carbonised plant debris		grit; small gravel
	22-32	3/4 7.5 YR	clay loam	subangular blocky					increase in small black gravel; hallophane
^	32-34	5/8 5 YR	clay	cemented layer				sedges; grasses	sand and grit or hardened clay in matrix; major break (burnt clay floors-pyroclastic flow?)
*	34-53	4/4 7.5 YR	clay loam	fine crumb structure			carbonised plant debris		large inclusions of compact clay (6/6 7.5 YR); also hard gray clay (9/5 7.5 YR?) grading into a sandy clay
	53-55	6/2 7.5 YR	ash?		organics				laminated, dense and brittle
*	55-61	4/4 7.5 YR	clay loam	fine crumb			carbonised plant debris		reddish yellow and light gray mottles
^	61-64	5/1 5 YR	clay loam	fine crumb				rice; banana; sedge; diverse palms	burn or ash level; background material dense with abundant, vein-like red mottles (4/6 2.5 YR); some hallophane crystals; visible pore space
*	64-75	4/4 7. 5YR	clay loam	fine crumb			carbonised plant material		some small inclusions; reddish brown and light gray dense clay w/infrequent hallophane crystals; pumice at 75 cm
16a.2	0-5	3/2 7. 5YR	silty clay	loose crumb	plant debris				small black granular particles
	5-7	3/2 7. 5YR	silty clay	loose crumb	plant fibre				no change
	7-10	3/4 7.5 YR	silty clay	loose crumb					granular
	10-15	4/6 10 YR	sandy loam	fine crumb					scattered black gravel inclusions; very loose
*	15-20	3/6 10 YR	sandy loam	fine crumb			plant debris		small scattered inclusions
	20-25	3/6 10 YR	sandy loam	fine crumb					top 2 cm w/silty/sandy inclusions; black gravel and hallophane
	25-30	6/3 and 3/4 10 YR	sandy loam	fine crumb					ash? inclusions
^	30-35	3/4 10 YR	sandy clay loam	fine crumb				low count	scattered yellow inclusions; black gravel
*	35-39	3/4 10 YR	sandy clay loam	fine crumb	visible plant material		degraded		large inclusions
	39-45	3/6 10 YR	sandy clay loam	fine crumb					6/2 10YR inclusions; most soil is a yellow matrix
	45-50	4/6 10 YR	sandy clay loam	fine crumb					5/2 2.5 YR inclusions; pore space like air bubbles black grit/gravel
	50-55	3/6 10 YR	silt loam	fine crumb					ash layer in top 2-3 cm; less grit and sand than material above
*	55-60	4/6 10 YR	silt loam	fine crumb			degraded		gray pumice and numerous black gravel
^	60-65	4/6 10 YR	sandy silt loam	fine crumb				low count	40% pumice ash; 6/1 10 YR ash

continued ...

Table 1 continued

	65-70	5/6 10 YR	silt loam	crumb					7/4 10 YR ash/pumice inclusions
*	70-75	5/6 10 YR	sandy silt loam	crumb			degraded		chunk of pumice; 60-70% or sample
16a.3	0-5	3/4 10 YR	sandy loam	crumb	plant remains				scattered inclusions of pumice
	5-10	3/6 10 YR	sandy loam	crumb					Inclusions of ash/pumice
	10-15	3/4 10 YR	sandy loam	crumb					30% pumice; black gravel/grit particles
*	15-20	4/4 10 YR	sandy silt loam	crumb			degraded		30% pumice; some large pieces
	20-25	4/6 10 YR	sandy silt loam	crumb					60% pumice; mostly gray
	25-30	4/6 10 YR	silt loam	crumb					50-60% pumice
	30-35	4/6 10 YR	silt loam	crumb					80% pumice (2 large pieces)
*	35-40	3/6 10 YR	silty clay loam	crumb			carbonised plant debris		50% pumice
^	40-45	3/6 10 YR	sandy silt loam	crumb				low count	50-60% pumice
	45-50	3/3 5 YR	sandy silt loam	crumb					mixture of gray pumice and cemented material; 50% pumice
	50-55	4/6 10 YR	silty clay loam	crumb					30% gray pumice
*	55-60	4/4 7.5 YR	sandy silt loam	crumb			degraded		black sand sized particles; 1% pumice
^	60-65	4/6 7.5 YR	sandy silt loam	crumb				diverse plants	10% pumice
*	65-70	4/6 7.5 YR	sandy silt loam	crumb			degraded		40% gray pumice; little matrix
16a4 #	0-5	3/6 10 YR	sandy silt loam	crumb	wood fragment	AD 1445±20			50% pumice; scattered charcoal
	5-10	3/4 7.5 YR	sandy silt loam	crumb					weathered yellow pumice fragments; black gravel/grit
	10-15	3/4 7.5 YR	sandy loam	crumb					inclusions of weathered pumice
*	15-30	3/4 7 YR	sandy loam	crumb			degraded		gritty matrix; numerous black particles; very scattered pieces of weathered pumice
^	30-35	3/4 7 YR	sandy loam	crumb				low count	no change from above; may be a little more cohesive
*	35-40	3/4 7 YR	sandy loam	crumb			degraded		weathered hard piece of pumice at 36 cm; rest as above
	40-45	3/4 7 YR	sandy loam	crumb					no change
	45-55	7/4 & YR	silty clay loam	crumb					numerous inclusions of yellow weathered pumice/ash; black grit/gravel; red/orange mottles
*	55-60	3/4 7 YR	silt loam	crumb			degraded		black pumice, may be coated; appears fire scarred
^	60-65	3/4 7 YR	silt loam	crumb					1 small piece of fine scarred pumice
	65-70	3/4 7 YR	sandy silt loam	fine crumb				economic arboreal	few inclusions of weathered pumice
*	70-73	3/4 7 YR	sandy silt loam	fine crumb			degraded		no change
	73-75	3/4 7 YR	sandy silt loam	fine crumb					abundant fire scarred pumice

continued ...

Table I continued

16a5	0-10	3/6 and 4/6 10 YR	sandy silt loam	fine crumb					granular; fairly well cemented
	10-15	4/6 10 YR	silt loam	fine crumb					yellow weathered pumice; well cemented red/brown inclusions
*	15-20	4/6 10 YR	sandy silt loam	fine crumb			degraded		some orange mottles; scattered gray pumice
	20-25	4/6 10 YR	sandy clay loam	fine crumb					fine matrix; less ash/pumice; tends to separate into blocks
	25-30	4/6 7.5 YR	sandy loam	fine crumb					very small inclusions; some weak layering
^	30-35	4/3 10 YR	silt loam	fine crumb				economic arboreal	mid-large inclusions
*	35-40	3/6 10 YR	silt loam	fine crumb			degraded		possible fire-baked red/brown material
	40-45	3/6 10 YR	silt loam	fine crumb					same as above with less hard material
	45-50	4/4 10 YR	sandy silt loam	angular					few scattered orange mottles; yellow inclusions
	50-55	3/6 10 YR	silty clay	angular					baked hard in places; generally silty texture between inclusions
*	55-60	3/6 10 YR	sandy clay loam	blocky			degraded		granular; scattered orange mottles; yellow inclusions
^	60-63	4/3 10 YR	sandy silt loam	blocky				economic arboreal	granular with scattered yellow inclusions
	63-64.5	4/6 7 YR	silt loam	blocky					oxidised
	64.5-68.5	3/4 10 YR	silt loam	blocky					finely laminated; no oxidation; fairly cohesive
	68.5-72	4/3 10 YR	silty clay loam	blocky					homogenous; no inclusions
#	72-74	4/3 10 YR	silty clay loam	blocky	wood	modern (bad date)			no change
	74-78	4/3 10 YR	silt loam	blocky					fine grained silt matrix; small pumice inclusions
*^	78-83	3/4 10 YR	sandy silt loam	blocky			degraded	economic arboreal	granular; less cohesive

* = pollen sample
^ = phytolith sample
# = date sample

or charcoal, derived from burning plant material is reported, at 215 cm BSD, with firing consistently present above 105 cm BSD. The pollen preservation of this core was generally very poor, but the origin of the burning is posited to be anthropogenic.

Phytolith analysis demonstrates that core 16 contained rice remains at 65 cm BSD as well as evidence for banana sometime after AD 1445. Below this depth are high percentages of arboreal phytoliths, dominated by palms. "The dominance of palms in the sequence, and the frequency of potential economic species, suggests that this may have been a 'managed' forest" (Kealhofer n.d.:4). Kealhofer makes the important point, however, that the influence of pumice and volcanic ash in the lower reaches of the cores may have altered soil chemistry or affected the relocation of plant material significantly. Nevertheless, the existing evidence for the dominance of palms in an area where they would not be expected does suggest an early forest management adaptation before AD 1445, followed by an increasingly intensive rice production strategy.

The fact remains that nearly 3 m of soil was deposited at this location during a 500-year period at a minimum, if we can accept the date presented. This area above the water temple appears to have experienced periodic episodes of alluvial or colluvial deposition interlaminated with burning events. The coring record permits very little chance of defining artefactual associations, so we do not know the precise influence of humans on this land surface. We conjecture that the temple grounds were periodically encroached on by direct volcanic deposition or redeposition of ash and pumice colluvium, by fluvial deposits following heavy wet-season rains after infrequent volcanic eruptions and by early and poorly managed soil regimes of farmers further upslope. The observed frequency of burning after each depositional event may be a response to the rapid regeneration of non-economic plant species in proximity to the temple grounds and may represent attempts to clear this zone of unwanted entanglement and encroachment by snakes and related pests – a condition apparent at this location today. However, a sustained agricultural adaptation to this small plot, with burning to clear fields, may be a more reasonable explanation, given the rice phytoliths found at 60-65 cm BSD. (It should be noted that a second AMS date was retrieved from core 16 at 432 cm BSD, yielding a date early in the 20th century, one believed intrusive [probably carbonised root; Nicholas Dunning, *pers. comm.*, 1998]. An event affecting matrices deposited to this depth within living memory would have been conveyed to us by the temple functionaries, we assume.)

At AD 1445 the upper portion of the inner courtyard was likely 1 m above the core 16 area sediments immediately to its north. We still do not know the age of the temple complex, but the setting is speculated to have been periodically cleared of non-economic plants and subsequently converted to a major water temple locus (see below). The elevated position of the temple platform at this time allowed for the movement of water-borne debris through the complex. Although pollen preservation was not good in core 16, it was best near the base of the core suggesting a less turbulent depositional environment. However, with the changes in the landscape associated with intensive rice production, sizable amounts of sediment were displaced downslope over time, an expected condition when experimenting with paddy formation on steeply inclined hillsides subject to heavy-seasonal rainfall. It is posited that more recent experience allows for the predicted slumping of paddy margins with the deliberate relocation of soils. In the distant past, this was a less deliberate event.

Considerable maintenance is implied by the volume of sediment which has infilled behind the temple complex; additional sediments were likely manually transported away from the temple to aid in the construction of the first dam south and below the temple complex. Now covered by the elevated road/parking lot defining the southern perimeter of the ritual grounds – but apparent in an eroded cross-section at its eastern end – this ancient dam would have contained a seasonal watershed for dry season cropping further downslope.

Significantly, the amount of infilling associated with the period from 17,000 BP to AD 1445 in the temple complex was probably less than 6 m – although it is not known how much has eroded away or has been removed manually – while during the 500 years since AD 1445 nearly 3 m of sediment at a minimum has invaded the area. Human induced aggrading from the modification of upstream landscapes is inferred.

Core 14 was located in the outer courtyard of the water temple and was examined for pollen as well as matrix depositional history. The two AMS dates taken at 63 cm and at 100 cm BSD produced modern associations, suggesting carbonised root intrusions from within this highly water-saturated setting (Nicholas Dunning, *pers. comm.*, 1998). Generally, the pollen preservation was again poor. Nevertheless, the lower half of the first meter of core sediment produced abundant pollen and spores dominated by sedges and grasses, with "3-5% of pollen grains that fall within the size range occupied by rice" (Haberle 1998a, 1998b). An isolated phytolith sample taken at 63 cm BSD revealed a composition of grasses similar to that defined in the upper reaches of core 16 and suggests to Kealhofer (1999:3) that "it is quite likely ... that rice was also present in these contexts." The fact that rice is not planted in the immediate proximity today suggests that the water temple courtyard was a planting surface in antiquity. Although the tree and herb pollen indicators were sparse, those that were present reflect a disturbed environment.

The date for the possible use of the outer courtyard as a field remains unknown, but it is unlikely that it was cropped in recent history – since the early 1900's – given our interviews with temple staff. Interestingly, immediately below the concentration of grass and sedge pollen in core 14 and continuing to a depth of 150 cm BSD were the repeated charcoal inventories that suggest possible anthropogenic fires. Is it possible that an earlier, less intensive, slash-and-burn cropping pattern was in place, only to be supplanted by paddy rice organisation?

Elsewhere in the coring operation, examples of thick, nearly uninterrupted volcanic scree are identified – especially in *sawah* cores 7, 8 and 9. Little datable matrix was retrieved from these contexts, though two additional AMS dates were run from cores 7 and 8. Each revealed a modern date – one from core 7 at 120 cm and another from core 8 at 284 cm BSD. Several explanations are possible, but the heavily water-saturated condition of these cores probably contaminated ancient organics. Although no pollen or phytolith analyses were attempted on cores 7, 8, and 9, considerable concentrations of pumice were identified. Core 9 was posed above a defunct tunnel segment – a tunnel cut into a soft pumice conglomerate that was penetrated at 3 m BSD. The fact that core 8, 45 m north of core 9, was derived from the same terrace surface as core 9, yet reveals a sedimentation history without the same extreme density of pumice, suggests the dynamic depositional history of the *sawah* setting. Core 8 probably reflects an earlier cut-away section of the channel – cut through the soft pumice – carrying water from an ancient source to the abandoned tunnel near core 9, a channel that was subsequently buried by the aggrading deposits eroding from the upper temple complex.

Core analyses have proceeded slowly but initial data and their interpretation suggest a degree of concordance with our model. Future reconstructions will require the coring of an ancient small lake or tank in proximity to the temple grounds as well as the initiation of formal open excavation exposures to aid in the identification of datable artefactual associations.

CONCLUSIONS

The sediment history from Pura Gunung Kawi Sebatu and the adjacent paddy fields hints at a transitional period in the economic and political development of ancient Bali. Before AD 1445, and inclusive of the 11th-century period of monumental construction at nearby Gunung Kawi and Tirta Empul, the engineered landscape of the Pura Gunung Kawi area was undeveloped and likely was defined by a managed forest setting dominated by palms. Although monumental Gunung Kawi and Tirta Empul were built less than 3 km to the southeast, the centralising processes associated with such acts of early statecraft did not immediately affect the Sebatu area. After AD 1445, however, the coring data indicate that the landscape was markedly altered with intensive paddy field agriculture eventually put in place. Containing sediment behind dams, weirs, and paddy bunds permitted the kind of landscape that is ethnographically associated with Bali. Given that the engineered landscape at Sebatu developed significantly after the disappearance of the 11th-century monumental centers, we posit that the dispersed *subak* organisations and their coordinating water temples successfully replaced the initial experiment in centralised state control, resulting in the heterarchical system of economic and political order identified ethnographically.

The self-organisation of the early *subak* system is suggested by Lansing's (1991; Lansing and Kremer 1993) ethnographic work. With the rapid transfer of information dealing with new and better ways of cropping rice, increased exchange occurred within and between *subak* at the water temples. Although *subak* groups were often separated by ridges, coordination was possible at the local level through the *subak* heads, water priests and related functionaries. Distant *subak* members could be knit together by the long canal and tunnel tethers bringing them back to the water temple. A higher tier of *masceti* or *ulun swi* temples often organised several water temples and their tethered *subak*, providing forums for the dissemination of information. We posited that the inherent fragmentation in the regional decision-making economic body allowed for greater experimentation at the local level and accelerated the pace at which the local landscape could be altered.

An accretional model for the modification of tropical and semitropical environments, making them useable – "harvestable" – is a scenario Scarborough has previously elaborated in the Maya region of Central America (Scarborough 1993, 1994). He argues, as do others, that such environments are defined by great species diversity, but little abundance of any one specific species in any single niche or patch (Scarborough 1998). The archaic states evolving in these settings adapted to this dispersed resource base in a manner markedly different from that of early states in semiarid settings positioned along the great riverways of the world. Early on, the political economies of tropical archaic states emphasised the interconnectivity of dispersed resources, discovering and refining the ecological pathways that made usable resources accessible to humans.

Many definitions of statecraft emphasise centralisation and resource concentrations controllable through power relationships (Carneiro 1970; Flannery 1972; Wright 1986). Although this interpretation of political economy merits attention within the context of tropical states, another prominent factor less well understood is the role of humans and their landscape outside the centralising nodes – defined archaeologically by monumental architecture and population density – and the connectivity of information and access to resources.

The ethnographic case from Bali indicates the dispersed character of the decision-making process. Rice cultivation at the dependency level identified on Bali could lend itself to more centralised control – an agenda popular with today's large international banking agencies (Lansing 1991:113) – but this was not the path taken in pre-colonial Bali. On Bali, culture and agriculture have long prospered because of a sophistication about the landscape derived from evaluating ecological and economic relationships within the evolving engineered environment. The convoluted pathways that information appears to travel in the self-organising Balinese case probably typifies other tropical settings that extend over highly engineered landscapes. Because these environments were altered slowly and incrementally over many generations, information and resource flows follow many natural pathways – those pathways least resistant to the early requirements of humans. However, these relationships for communicating and acquiring resources were always flexible and opportunistic, given the fragility of some tropical settings and the risk of overtaxing any one set of resources.

The results of these organisational efforts on Bali were not the centralising nodes *per se*, but rather the interplay across the landscape of groups intent on exploiting the water pathways and incorporating their sometimes meandering courses to tap the best water, soil, gradient, and microclimate. The landscape history as symbolised by the numerous shrines and water temples was fundamental in the decision-making process too. Without densely occupied towns and cities, the Balinese developed an effective, decentralised political economy.

Using the popular assessment of the evolving archaic state by Blanton *et al.* (1993), Bali was complex – both vertically and horizontally differentiated – highly integrated, and of sizable scale. Precolonial Bali had fewer people and resources at any one point on the landscape, but many more people dispersed across it, than would be expected based on models of urbanism and nucleation derived from early experiments in statecraft within semiarid settings. The island-wide density of Bali today is at least 520 people/km^2 (Lyon and Wheeler 1997:25), and the village of Sebatu reports a local figure of 571 people/km^2 over a 10.9 km^2 area including 2.8km^2 of rice paddies and 7.4km^2 of dry agricultural fields (Desa Sebatu 1988). These highly integrated "rural" poplations are and were extremely knowledgeable about their diminutive landholdings, and they depend on producing food through intensification. In a fragile environment, this means creating a series of highly controlled micro-swamp settings.

A significant aspect of the Balinese landscape is the role of the informed farmer. Usually the most knowledgeable members of the *desa* (village) or *subak* councils are the farmers themselves. Not only are they familiar with the micro local decision-making outlined above, but they know long and accurate segments of ritualised knowledge undergirding Balinese culture, knowledge more generally associated with and privileged to the literate élites of highly centralised societies.

On Bali, a social coordination based on small-scale, local networks evolved, pulling the sustaining population away from the centralising nodes. It was this interconnectivity of information and its pathways that permitted a decentralised but highly efficient decision-making system. This system was grounded in its inseparable tie to the changing built environment, a dynamism based on local decision making and rapid information exchange with other farmers and neighbouring communities.

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NOTES

1. This paper was originally prepared for the 16th Congress of the Indo-Pacific Prehistory Association Meetings in Melaka, Malaysia, of July, 1998. A more comprehensive version of this manuscript entitled, Early Statecraft on Bali: The Water Temple Complex and the Decentralization of the Political Economy, has been published in the anthropological yearbook, *Research in Economic Anthropology* Volume 20 (Scarborough, Schoenfelder, and Lansing 1999). This abstracted and abbreviated version of the *REA* contribution is republished here to allow the inclusion of Table 1 data to be presented for the first time.

REFERENCES

Ardika, I W. 1987. Bronze Artifacts and the Rise of Complex Society in Bali. MA dissertation, Australian National University, Canberra.

Ardika, I W. 1991. Archaeological Research in Northeastern Bali. PhD dissertation, Australian National University, Canberra.

Ardika, I W. 1994. *Pertanian Pada Masa Bali Kuna: Suatu Kajian Epigrafi. Laporan Penelitian.* Denpasar: Universitas Udayana.

Ardika, I W. and P. Bellwood. 1991. Sembiran: The beginnings of Indian contact with Bali. *Antiquity* 65:221-32.

Ardika, I W. and Ni Luh Sutjiati Beratha. 1996. *Perajin Pada Masa Bali Kuna Abad IX-XI Masehi.* Denpasar: Fakultas Sastra Universitas Udayana.

Barth, F. 1993. *Balinese Worlds.* Chicago: University of Chicago Press.

Bellwood, P. 1997. *Prehistory of the Indo-Malaysian Archipelago* (rev. ed.). Honolulu: University of Hawai'i Press.

Bellwood, P., R. Gillespie, G.B. Thompson, J.S. Vogel, I W. Ardika and Ipoi Datan. 1992. New dates for prehistoric Asian rice. *Asian Perspectives* 31:161-70.

Bentley, G.C. 1986. Indigenous states of southeast Asia. *Annual Review of Anthropology* 15:275-305.

Bernet Kempers, A.J. 1991. *Monumental Bali.* Berkeley, California: Periplus Editions.

Blanton, R.E., S.A. Kowalewski, G.M. Feinman and L.M. Finsten. 1993. *Ancient Mesoamerica: A Comparison of Change in Three Regions* (2nd ed.). Cambridge: Cambridge University Press.

Carneiro, R.L. 1970. A theory of the origin of the state. *Science* 169:733-8.

Covarrubias, M. 1937. *Island of Bali.* New York: Alfred A. Knopf.

Desa Sebatu 1988. *Lambang Desa Sebatu.* Denpasar: Direktorat Pembangunan Desa, Pemerintah Propinsi Dati I, Bali.

Dumarcay, J. 1986. *The Temples of Java.* Oxford: Oxford University Press.

Flannery, K.V. 1972. The cultural evolution of civilizations. *Annual Review of Ecology and Systematics* 3:399-426.

Geertz, C. 1980. *Negara: The Theatre State in Nineteenth-Century Bali.* Princeton,: Princeton University Press.

Goris, R. 1954. *Prasasti Bali: Inscripties voor Anak Wungcu.* Bandung: N.V. Masa Baru.

Haberle, S. 1998a. Report on the Gunung Kawi Sebatu pollen samples: Cores 16 and 14. Unpublished manuscript.

Haberle, S. 1998b. Second report on the Gunung Kawi Sebatu pollen samples: Cores 14 and 17. Unpublished manuscript.

Kealhofer, L. 1999 Preliminary phytolith report: Core 16, Sebatu, Bali. Unpublished manuscript.

Lansing, J.S. 1987. Balinese 'water temples' and the management of irrigation. *American Anthropologist* 89:326-41

Lansing, J.S. 1991. *Priests and Programmers: Technologies of Power in the Engineered Landscape of Bali.* Princeton: Princeton University Press.

Lansing, J.S. 1995. *The Balinese.* New York: Harcourt Brace College Publishers.

Lansing, J.S. and J.N. Kremer. 1993. Emergent properties of Balinese water temples. *American Anthropologist* 95:97-114.

Liefrinck, F.A. 1969. Rice cultivation in northern Bali. In J.L. Swellengrebel (ed.), *Bali: Further Studies in Life, Thought and Ritual*, pp. 3-73. The Hague: M. Nijhoff.

Lyon, J. and T. Wheeler. 1997. *Bali and Lombok.* Hawthorn, Australia: Lonely Planet.

McTaggart, W.D. 1988. Hydrologic management in Bali. *Singapore Journal of Tropical Geography* 9:96-111.

Miksic, J. 1996. *Ancient History. Indonesia Heritage 1.* Jakarta: Budu Antar Bangsa for Grolier International.

Miksic, J. n.d. Environment and civilization in early Indonesia. Paper presented at the 85th Annual Meeting of the American Anthropological Society, San Francisco, 1996.

Reconnaissance Soil Map for the Bali Irrigation Project 1985. Report to the Ministry of Public Work, Directorate General of Water Resources, Directorate of Irrigation, Bali Irrigation Project. Denpasar: Udayana University, Faculty of Agriculture.

Scarborough, V.L. 1993. Water management systems in the southern Maya lowlands: an accretive model for the engineered landscape. In V.L. Scarborough and B.L. Isaac (eds.), *Economic Aspects of Water Management in the Prehispanic New World*, pp. 17-69. Greenwich, Connecticut: JAI Press, *Research in Economic Anthropology Supplement* 7.

Scarborough, V.L. 1994. Maya water management. *National Geographic Research and Exploration* 10:184-99.

Scarborough, V.L. 1998. Ecology and ritual: water management and the Maya. *Latin American Antiquity* 9:135-59.

Scarborough, V.L., J.W. Schoenfelder and J.S. Lansing. 1999. Early statecraft on Bali: the water temple complex and the decentralization of the political economy. *Research in Economic Anthropology* 20:

Schoenfelder, J. 2000. The co-evolution of agriculture and sociopolitical systems in Bali. *Bulletin of the Indo-Pacific Prehistory Association* 20(4): 35-47 (this volume).

Setiawan, I.K. 1995. Subak: Organisasi Irigasi Pada Pertanian Padi Sawah Masa Bali Kuno. Magister Humaniora thesis, Universitas Indonesia, Jakarta.

Soejono, R.P. 1977. Sistem-sistem Penguburan Pada Masa Prasejarah di Bali. PhD dissertation, Universitas Indonesia, Jakarta.

Stutterheim, W.F. 1935. *Indian Influences in Old-Balinese Art.* London: India Society.

Suadnya 1990. *Mengenal Subak.* Denpasar: Dinas PU.

Sutaba, I.M. 1980. *Prasejarah Bali.* Denpasar: B.U. Yayasan Purbakala Bali.

Wright, H.T. 1986. The evolution of civilizations. In D.J. Meltzer, D.D. Fowler and J.A. Sabloff (eds), *American Archaeology: Past and Future*, pp. 323-65. Washington: Smithsonian Institution Press.