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Karst Geomorphology

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AQUATIC INSECT LARVAE AS GEOMORPHIC AGENTS IN TRAVERTINE-BUILDING: A CASE STUDY FROM THE BARKLY KARST, AUSTRALIA

ABSTRACT: DRYSDALE R., *Aquatic insect larvae as geomorphic agents in travertine-building: a case study from the Barkly Karst, Australia.* (IT ISSN 0391-9838, 1998).

Louie Creek (18° 49'S, 138° 29'E) is a karst spring-fed creek that drains the northeastern Barkly Karst, northern Australia. The stream deposits travertine along a reach of approximately 1.5 km. Although physico-chemical processes dominate the downstream evolution of the bulk solution, aquatic insect larvae play both a direct and an indirect geomorphological role in travertine deposition at the microenvironment level. The most conspicuous roles are played by simulids and chironomids (Order: Diptera), pyralids (Order: Lepidoptera) and hydropsychids (Order: Trichoptera). The latter are by far the most important fauna. The dominant genus (*Cheumatopsyche*) constructs cylindrical cases and silk nets on the travertine surfaces, especially where strong currents prevail. Cases consist of local materials, including travertine quarried from the stream bed. The nets are usually erected between cases or constructed over the case openings. They serve to trap food carried downstream in suspension. Both nets and retreats are important substrata for calcium carbonate deposition and interrupt stream flow due to their considerable microrelief.

KEY WORDS: Travertine, Aquatic Macroinvertebrates, Barkly Karst, Australia.

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INTRODUCTION

Travertines are terrestrial, chemical sedimentary rocks of predominantly karstic or geothermal origin composed primarily of the calcium carbonate minerals, calcite and aragonite. They form in a wide variety of hydrogeological settings, differ widely in terms of physical structure, and may develop into one of numerous classes of geomorphological feature (Chafetz & Folk, 1984; Pentecost & Viles, 1994). In karstic terrains, travertines are usually deposited from cool carbon dioxide-rich groundwaters containing a relatively high dissolved load of calcium carbonate. Upon exposure to the atmosphere, the carbon dioxide is rapidly outgassed and the waters become supersaturated with respect to calcium carbonate. Consequent precipitation of calcite occurs around virtually any prevailing substrata, including clastic sediments, higher plants, microflora and aquatic invertebrates. As cementation progresses, distinctive morphological features, such as gour pools, cascades and barriers, are formed. Depending on site conditions, these may develop over time into massive geomorphological features that may drastically alter regional hydrology and control subsequent landscape development (Emeis & *alii*, 1987; Burger, 1990; Drysdale & Gale, 1997).

Travertine researchers have long debated the relative importance of physico-chemical and biological processes in calcium carbonate precipitation and the precise nature of the role played in travertine formation by microbes such as cyanobacteria and diatoms. It is universally agreed that microbes at the very least offer surfaces onto which crystal nucleation can occur. Whether or not such nucleation (and subsequent crystal growth) is stimulated primarily by biochemical activity is less easily resolved, partly because it occurs within a bulk solution that is already supersaturated with respect to calcite. Few researchers, however, have considered the geomorphic role played by microorganisms or the role played by other aquatic life, such as invertebrates, in travertine formation. It is the aim of this correspondence to report the results of an exploratory investigation into the geomorphological role of aquatic insect larvae in a tropical travertine-depositing karst stream.

STUDY SETTING AND BACKGROUND

The Barkly Karst is one of Australia's largest continuously exposed limestone terrains. Situated in northwest Queensland and northeastern Northern Territory (fig. 1), the karst is subject to a strongly seasonal tropical climate consisting of hot, humid summers and mild, dry winters. The annual rainfall is highly variable in amount but highly predictable in timing, falling primarily between December and March. Groundwater in the better-watered northeastern segment of the karst discharges via the perennially spring-fed Gregory River, O'Shanessy River, Lawn Hill Creek and Louie Creek (fig. 1), each of which ultimately drains to the Gulf of Carpentaria. It is the latter of these fluvial systems that forms the focus of this study.

With the exception of during and immediately following wet season floods, Louie Creek is fed solely by small seepages that rise through the stream bed. Travertine formation commences a little over a kilometre from the major exsurgence points and occurs in two contrasting geomorphic settings:

1. Cascades and dams – each set consisting of a maze of small rimstone dams separated by relatively shallow pools. A larger barrier – or «terminal barrage» – usually occurs at the downstream end of each set of cascades.

2. Waterholes – long, linear bodies of almost standing water comprising *in situ* stromatolitic travertines as well as unconsolidated to partly cemented allochthonous travertine fragments.

Travertine deposition rates, which have been measured using a micro-erosion meter, vary considerably (Drysdale & Gillieson, 1997). In standing water, rates are uniformly very low, less than 0.4 mm per annum, whilst under more vigorous hydraulic conditions as much as 30 mm may be deposited per annum. Chemical analysis of the stream waters over a five-year period indicates that strong outgassing of carbon dioxide occurs over the initial kilometre of surface flow. By the time the waters reach the point where travertine formation commences they are between five and seven times supersaturated with respect to calcite. Deposition through the reach is assisted by the relatively steep longitudinal gradient, which physically enhances carbon dioxide outgassing and the propensity for calcite precipitation.

METHODS

Fresh travertine samples were collected from widely distributed sites along Louie Creek in October 1992 and April and October 1993. The sampling points were chosen on the basis of the scheme described in table 1 and portrayed in fig. 2. Aquatic insect larvae were detached from the surfaces of 73 samples with the help of a dissecting microscope, a pasteur pipette, a pair of tweezers, a scalpel and ethanol. Fauna were identified to at least the family level by entomologists at the Commonwealth Scientific and Industrial Research Organisation (Csiro) and the Environment Protection Authority of Victoria. The surfaces of several samples were examined under both dissecting and scanning electron microscopes, with the emphasis on evaluating the role of insect larvae in travertine formation and the extent (if any) to which this role constituted constructive and/or destructive geomorphic activity.

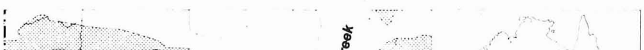

FIG. 1 - Location of Louie Creek, northwest Queensland, Australia. The shaded area is the exposed northeastern portion of the Barkly Karst.

FIG. 2 - Examples of each of the five hydraulic zones listed Table 1. S = standing water zone; SP = spray zone; L = lap zone; F = flow zone; I = impact zone.

TABLE 1 - The five hydraulic regimes identified in this study

Hydraulic zone	*Zone description*
Standing water (SWZ)	Water bodies of any depth whose flow velocity does not exceed 0.01 m s^{-1}; confined to stagnant pools, impoundments associated with large travertine barrages and waterholes.
Spray (SPZ)	Deflected water in the immediate vicinity of waterfalls and cascades; spray may range from a fine mist to an intense splash.
Lap (LPZ)	Pulses of lapping water generated by plunge pool turbulence.
Flow (FLZ)	Stream flow which is approximately normal to the cross section moving at a velocity exceeding 0.01 m s^{-1}; flow may occur at an inclination >0° and can include the passage of water down the steep face of a travertine barrage; includes seepage flow.
Impact (IMZ)	A column of water which becomes detached from the crest of a travertine barrage and strikes the substrate at the base of the barrage.

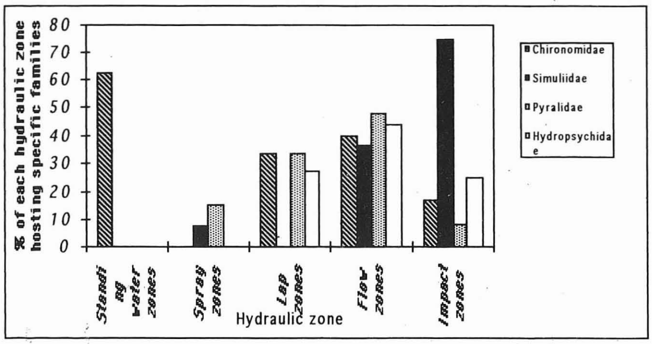

FIG. 3 - Hydraulic distribution of four major families of aquatic insect larvae, Louie Creek, Barkly Karst, Australia.

RESULTS

General distribution

A total of 12 families belonging to five insect Orders were extracted from the travertine samples (table 2); only three samples did not yield fauna. Dipteran, trichopteran and coleopteran larvae have been reported from travertine-depositing streams elsewhere (e.g. Thienneman, 1933; Schneider, 1977; Durrenfeldt, 1978). Of the 12 families represented, *Ceratopogonidae, Simuliidae, Chironomidae, Hydropsychidae* and *Pyralidae* stand out as being the most abundant. From a zoogeomorphological point of view, the relatively cosmopolitan *Ceratopogonidae* appear to exert no detectable direct influence, being essentially free-living and predatory. By contrast, each of the latter four has specific hydraulic preferences and plays an active and/or passive zoogeomorphological role.

TABLE 2 - Hydraulic distribution of aquatic insect larvae (by family), Louie Creek, Barkly Karst, Australia

LARVAE		*HYDRAULIC ENVIRONMENT*					
Order	*Family*	*Total (n=73)*	*Standing (n=8)*	*Spray (n=13)*	*Lap (n=15)*	*Flow (n=25)*	*Impact (n=12)*
DIPTERA (flies)	*Ceratopogonidae*	40	4	12	14	10	0
	Chironomidae	22	5	0	5	10	2
	Simuliidae	19	0	1	0	9	9
	Stratiomyidae	3	0	1	0	2	0
LEPIDOPTERA (moths/butterflies)	*Pyralidae*	20	0	2	5	12	1
TRICHOPTERA (caddis-flies)	*Ecnomidae*	1	1	0	0	0	0
	Hydropsychidae	18	0	0	4	11	3
	Philopotamidae	5	0	0	0	5	0
COLEOPTERA (beetles)	*Limnichidae*	1	0	0	1	0	0
	Hydrophilidae	4	0	3	0	1	0
	Scirtidae	9	0	0	3	6	0
EPHEMOPTERA (mayflies)	*Baetidae*	3	0	0	1	2	0

Chironomidae

The chironomids occur primarily in both flowing and standing water environments where depths exceed 3 mm; they were absent from spray zones and poorly represented in impact zones (fig. 3). They live in silken tubes that are attached to the travertine substrate (fig. 4a). The tube contains a claw-like extension which is used to trap food.

The chironomid tubes can be found individually or in thick clusters at travertine dam crests (fig. 4b). The tubes act as passive substrata for calcite precipitation. They become incorporated into the travertine structure and increase the overall porosity and apparent accumulation rate of the deposit. Chironomids therefore play a passive constructive role in travertine development at Louie Creek.

Simuliidae

Simulid larvae are sedentary animals that have a strong preference for fast moving water (fig. 3). They are physically adapted to withstand strong currents by fixing themselves to the travertine substrate by means of a posterior sucker. They strain the water for food using a filter-like mouth part.

During their larval stage, simulids build a cocoon in which they live as pupae. The cocoon is fixed to the travertine substrate and aligned parallel to water flow (fig. 4c) under high current velocity conditions. The cocoons serve as passive substrata for calcite precipitation and, as with chironomid tubes, become incorporated into the overall deposit. Although slightly larger in size than the chironomid tubes, the cocoons are much less abundant and thus exert a relatively small role in the microscale geomorphology of the travertines.

Pyralidae

Pyralids constitute one of the few families of moth whose larvae are aquatic. The individuals at Louie Creek appear to prefer moving water but not strong currents (fig. 3), being absent entirely in standing water zones and present only in the impact zone having the lowest discharge.

Pyralids are primarily constructive but may also be destructive. They build silken shelters or retreats which range in form from cylindrical tubes to marquee-like sheet structures that extend between interstices separating microtopographic highs on travertine surfaces (fig. 4d). In some instances, the organism appears to burrow through soft travertine (e.g. the spongy travertine that forms in a matrix of chlorophyta) then spin a tube in the void created (fig. 4e). Terrestrial moth larvae are well known for such bur-

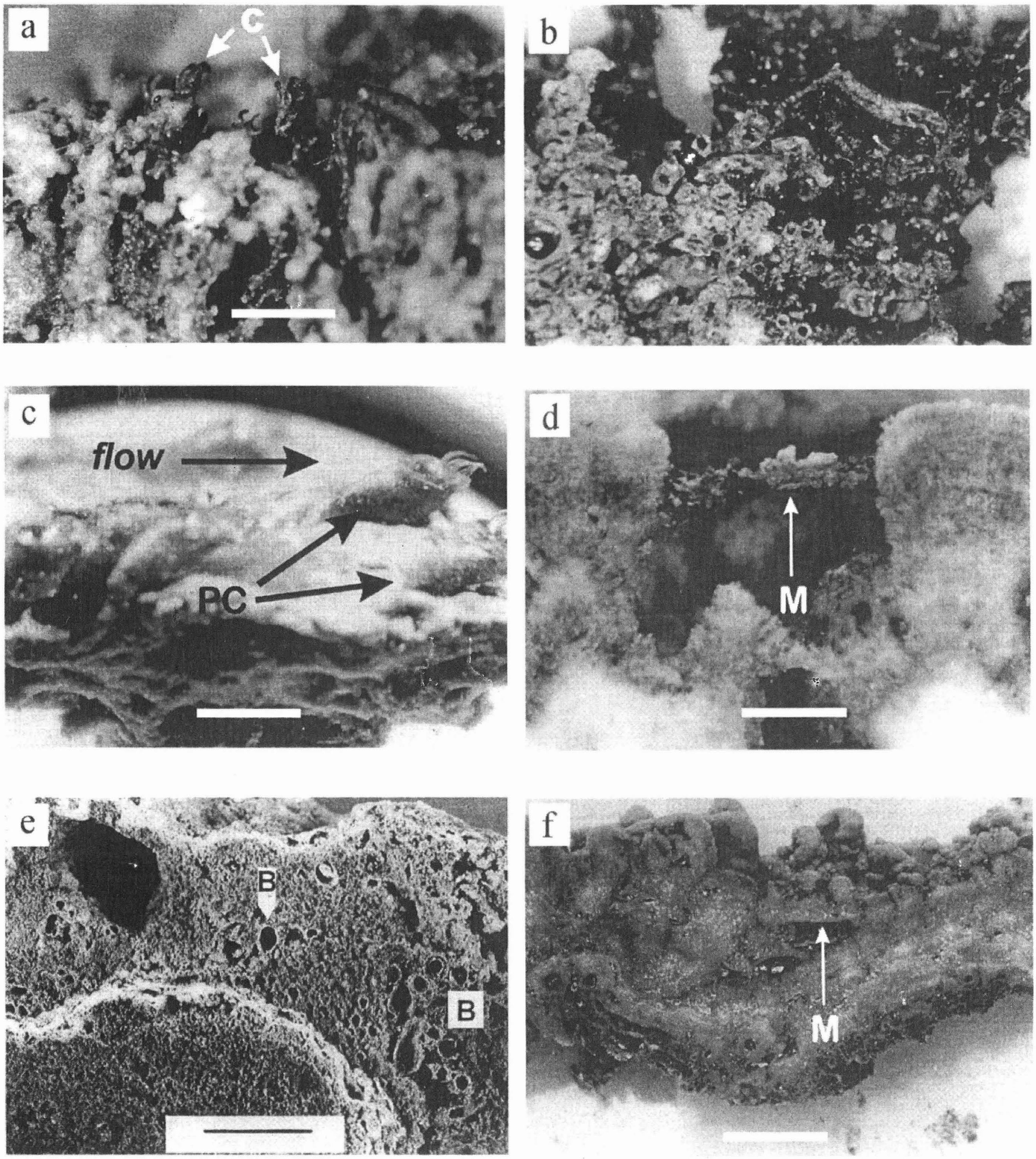

Fig. 4 - (a) Upright chironomid tubes showing claw-like extensions (C) used to trap food. The light coloured slightly out-of-focus clumps are $CaCO_3$ deposits. Light microscope view. Scale bar = 1 cm. (b) A cluster of chironomid tubes from a travertine dam crest. Calcium carbonate cementation increases from top (surface) to bottom (interior). Each tube is between 0.3 and 0.5 mm in diameter. Light microscope view. (c) Section view of a fractured travertine surface showing simulid pupae in their silken cases (PC) aligned parallel to stream flow. The hair-like strands protruding from the cases are used for respiration. Scale bar = 2 mm. Light microscope view. (d) Silken pyralid «marquee» (M) constructed between two nodular cyanobacterial microstructures (C). The animals live beneath such features. The top of the marquee is coated with a thin veneer of $CaCO_3$. Light microscope view. Scale bar = 2.5 mm. (e) Silk-lined pyralid burrows (B) formed in soft chlorophytic travertine. Scale bar = 2 cm. (f) Polished section of fresh travertine showing a marquee structure (M) preserved at depth, increasing the primary porosity of the deposit. Light microscope view. Scale bar = 1 cm.

rowing behaviour. Elsewhere, the tube has clearly occupied a fresh surface and erosional processes cannot be invoked. Both sheets and tubes offer sites for mineral precipitation and, on account of their size, increase the porosity of the travertine structure considerably (fig. 4f).

Hydropsychidae

Most of the hydropsychids were found in flow zones (fig. 3), where they favour strong currents. This preference for flowing water is well documented (e.g. Nebioss, 1991). The dominant genus at Louie Creek is *Cheumatopsyche* (Dr John Dean, Environment Protection Authority of Victoria, 1997, pers. comm.), a case- and net-builder from a family of collectors and gatherers (Nebioss, 1991).

The hydropsychids are by far the most geomorphologically significant insect larvae at Louie Creek. The cases in which they live are relatively elaborate and composed of sediments and organic detritus (fig. 5a) bound together by silk (fig. 5b). The cases are lined with silk and anchored to the travertine or organic substrate by silken strands which are welded or smeared to the substrate (fig. 5c), over which calcite may form. A silken net of ornate architecture is erected across the entrance to the case and is used to strain the water for food (fig. 5d). The nets often extend between two or more prominent fragments of detritus, such as rootlets, which act as supports in the same way that two poles support a volleyball net. It is possible to observe the animals emerging from their cases to scour their nets for food.

Electron microscope evidence indicates that the animals quarry travertine from the substrate. Figure 6a shows that the cases comprise regular, «bite-sized» pieces of travertine bound together with silk. The size of the travertine fragments may be compared with the mouth parts of the

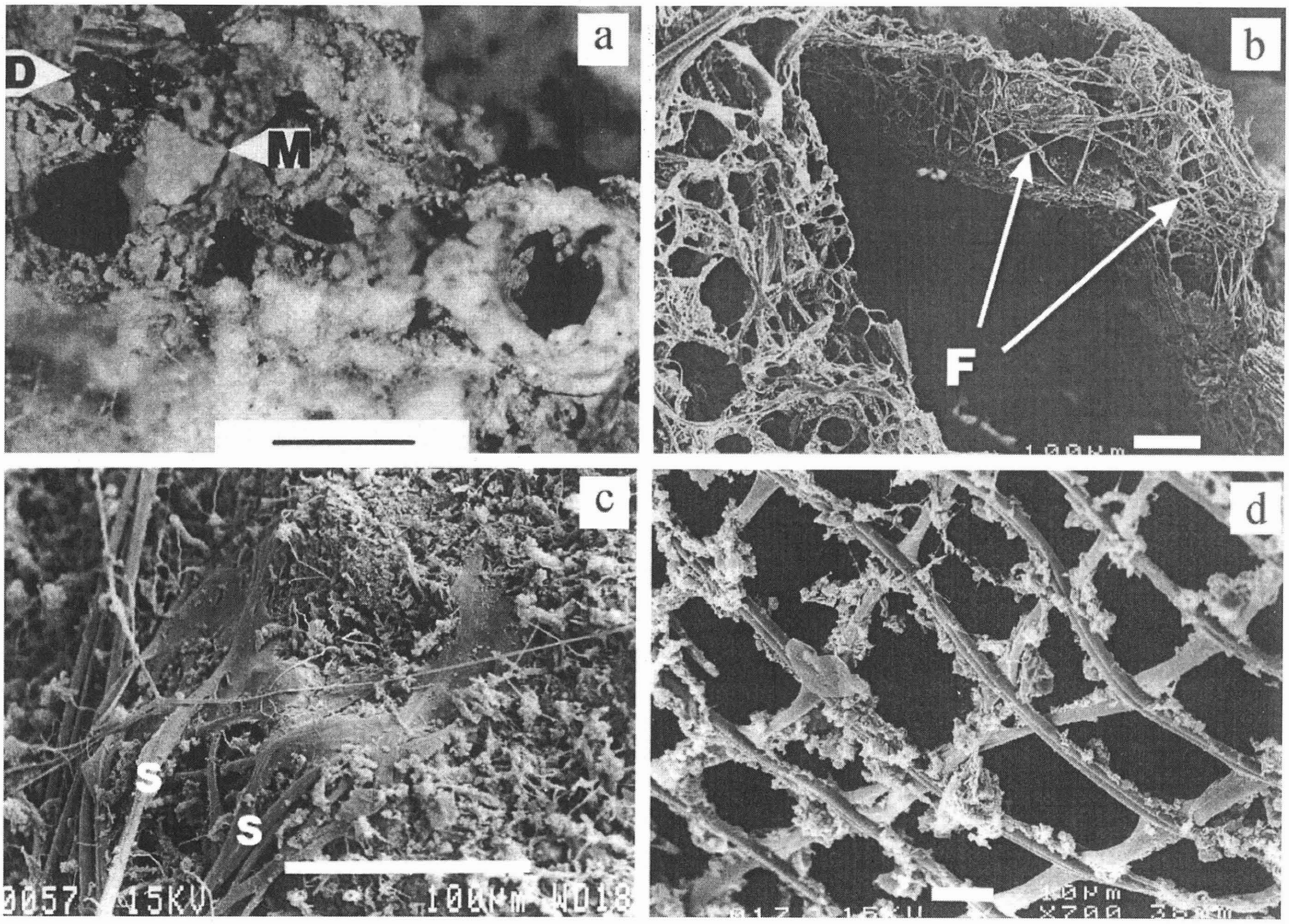

FIG. 5 - (a) Hydropsychid cases constructed of locally-derived plant materials (D) and minerogenic matter (M). Light microscope view. Scale bar = 2 mm. (b) Sem image of hydropsychid case detail showing individual fragments (F) bound together by silk strands. Scale bar = 100 µm. (c) Cases are often anchored to the travertine substrate by silk strands (S). Subsequent mineral precipitation over the anchor points would undoubtedly add strength to the case structure. Sem image. Scale bar = 100 µm. (d) Hydropsychid net, showing intricate architecture as well as food and other particles filtered from the water column. Such particles and the net surface itself act as nuclei for $CaCO_3$ precipitation. Sem image. Scale bar = 10 µm.

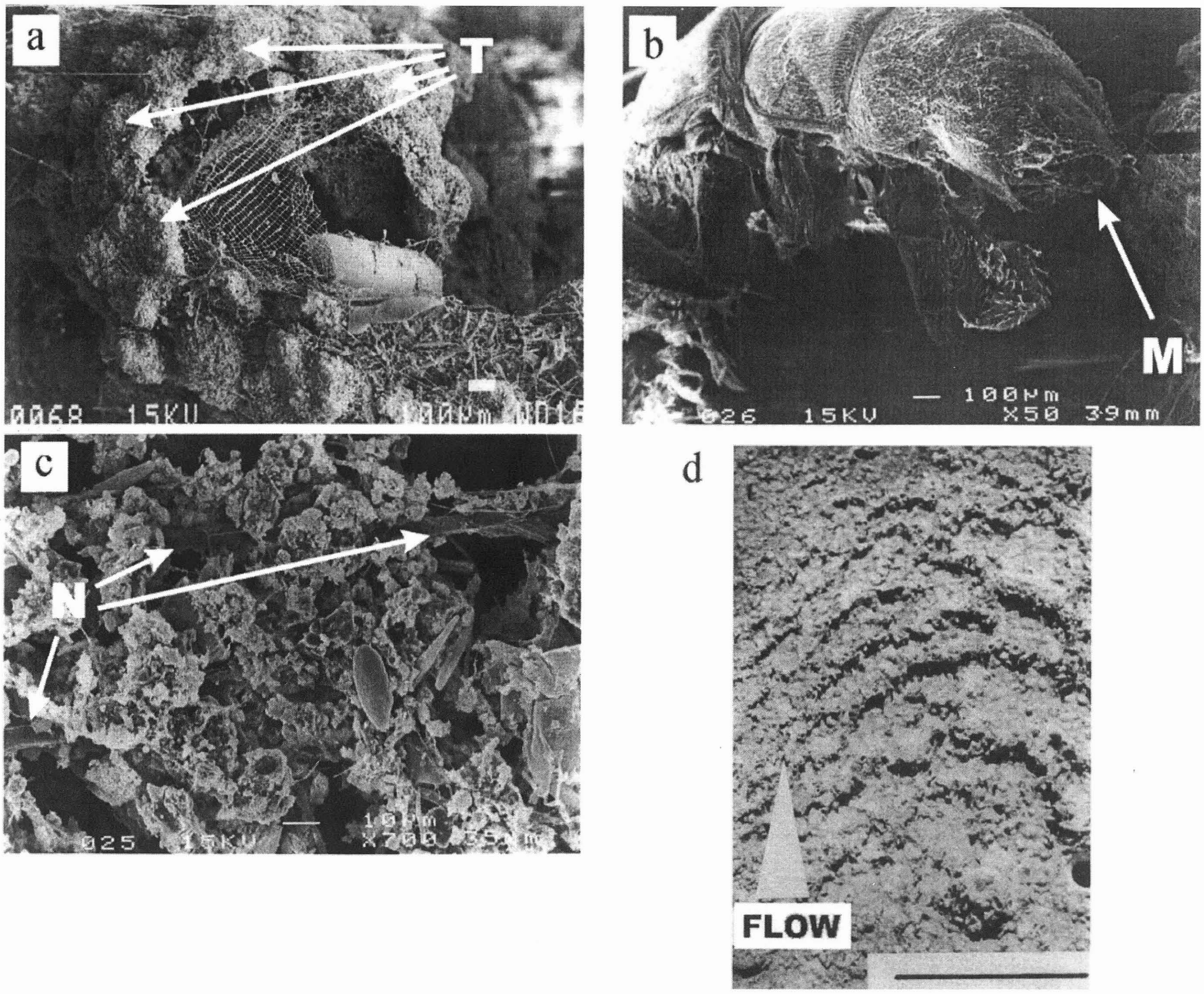

FIG. 6 - (a) Scanning electron microscope view of hydropsychid cases composed of individual travertine fragments (T) quarried from the substrate and bound together with silk. The remains of a net covering the case opening are visible. Scale bar = 100 µm. (b) Sem image of a *Cheumatopsyche* larva. The size of the mouth parts (M) corresponds well with the size of bound fragments shown in (a). Scale bar = 100 µm. (c) Over time the hydropsychid net (N) becomes clogged with suspended material and calcite. Sem image. Scale bar = 10 µm. (d) Arcuate linear arrays of calcite-encrusted hydropsychid nets and cases aligned ~normal to water flow. Artificial substrate surface. Scale bar = 5 cm.

animal (fig. 6b). Both nets and cases act as prominent sites for calcite precipitation to the extent that the nets become completely clogged with calcite and suspended debris (fig. 6c) (in spite of the best efforts of the larvae to clear them) and the cases become «sealed». Together the cases and nets regularly form arcuate linear arrays orientated approximately perpendicular to the flow of water (fig. 6d). These arrays may protrude up to 10 mm above the surface of the surrounding substrate. Such significant microtopographic relief serves at least two potentially important roles in travertine accumulation:

1. it would increase turbulence by interrupting flow hydrodynamics. This would enhance local carbon dioxide outgassing and calcite precipitation;

2. it would increase the propensity for suspended detritus to become entrapped. This would provide new carbonate nucleation sites and, in combination with (a), enhance the overall accumulation of travertine.

The contribution of cemented hydropsychid cases and nets to overall travertine deposition rates is particularly significant where «background» carbonate precipitation is low (Drysdale & Gillieson, 1997). Hydropsychids also appear to be strongly influenced by subtle changes in flow conditions. Small decreases in water level along Louie

Creek have been observed to shift hydraulic patterns from flow to lap zone conditions. This results in a cessation of larval activity and the commencement of cyanobacterial activity.

CONCLUSIONS

Although travertine formation invariably requires a bulk solution that is supersaturated with respect to calcite, a considerable degree of biological activity takes place at the sediment-water interface that ultimately influences the microscale geomorphic development of the travertine. The contribution of aquatic larvae to this biological role is poorly understood, although at Louie Creek they clearly play a key role under specific hydraulic conditions.

Of the larval families documented from travertine surfaces at Louie Creek, hydropsychids play the most significant role. Not only do they contribute to the mineral precipitation process in a constructional sense by introducing new nucleation sites into the microenvironment, but their case-building activities also involve a noteworthy destructive role. Several other larvae play a less significant though still readily observable role.

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