THE SEDIMENT BUDGET OF THE LILLOOET RIVER BASIN, BRITISH COLUMBIA

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Abstract: The sediment and solute budget of the Lillooet River basin in British Columbia (3,150 km^2) is developed to exemplify a methodology that has the potential to unify geomorphological research. Sediment and solute transport processes in Holocene time are identified and quantified. The budget is demonstrated to be severely unbalanced. Historical events and transient response to those events are implicated. A minimum of four time scales of integration—geological, Pleistocene, Holocene and contemporary—are proposed, and the role and status of the components of the sediment budget are examined. Storage sites and solute sinks, linkages among sediment and solute transport processes, the role of biotic factors, weathering, stratigraphic evidence, and the hydrologic balance are individually reviewed. Spatial scale considerations provide a way of interpreting and aggregating the above complex factors. In general, there appears to be no spatial scale at which sediment and solute supply from the slopes is in balance with storage change and yield over specified time periods. [Key words: sediment budget; sediment and solute transfers; glacierized, tectonically active mountain basin; Lillooet River, British Columbia.]

THE FRAMEWORK OF SEDIMENT BUDGET STUDIES

The energy budget in climatology and the hydrologic cycle in hydrology are examples of unifying concepts in physical geography. In the case of geomorphology, the geographical cycle was central prior to the 1940s and geomorphology grew rapidly in influence under this unifying concept. Since the discrediting of the Davisian cycle, geomorphology's intellectual energy has been dissipated in a number of directions (Tinkler, 1985). These directions do not necessarily add up to a coherent field, and a number of calls for a new focus for the field have appeared recently (e.g., Schumm, 1977; Brunsden, 1990; Baker and Twidale, 1992). As long as the field remains unfocused, geomorphology is vulnerable to internal divisions, and the possibilities for incremental and additive research are reduced.

Moreover, bandwagons that seem to offer cohesion but are intellectually flawed have become common. Timeless, theoretical, and utilitarian bandwagons are just three examples. Geomorphology that deals exclusively with functional relationships that ignore actual time sequences, or that considers exclusively theoretical constructs, or that defines itself in terms of solutions to applied problems is simply

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Fig. 1. Lillooet River Basin, British Columbia.

not true to its intellectual roots. Nor is it able to define a role in the academy that will command respect from other fields.

The sediment budget has the potential to embrace the traditional questions in geomorphology and allows growth in understanding of landforms as part of a dynamically vibrant planet. This potential is illustrated with a detailed application to the 3150 km^2-Lillooet River basin in the southern Coast Mountains of British Columbia (Jordan and Slaymaker, 1991; Figure 1).

The sediment budget equation, in the form

$$I = O + \Delta S \ldots., \tag{1}$$

where I is input, O is output, and ΔS is change of storage, can describe the routing of clastic and dissolved sediments over a specified time increment and with respect to a particular storage reservoir. Such a framework allows the interpretation of form change as the residual difference between input and output at specified spatial and temporal scales. In the unusual case where

$$I = O \ldots., \tag{2}$$

local form is unchanged and yet a net lowering of land mass relative to an absolute datum will have occurred.

Examples of application of the sediment budget approach to clastic sediment routing are numerous—those by Jackli (1957), Rapp (1960), Lehre (1982), Leopold et al. (1966), and Swanson et al. (1982) are perhaps the best known. They have identified the major sources, pathways, and sinks of clastic sediments within relatively small basins or landform units and determined process rates. Rapp also identified the important role of dissolved solids. They have not, on the whole, emphasized form changes because of the short periods of research involved.

Oldfield (1977) and Dearing et al. (1982) have linked lake basin sediment budget studies with solute routing, nutrient cycling, and ecology, and Foster et al. (1985) formulated a simple mass balance of sediment transfers in aquatic systems that includes the dissolved solids:

$$\Delta S = (I_f + I_c + I_o + I_s + I_b + I_a) - O \; \ldots \; , \qquad (3)$$

where ΔS = net accumulation of lake sediment during a specified time, Δt; I = input of sediment to the lake in time Δt; f = fluvial; c = colluvial; o = organic matter; s = biogenic silica; b = lake bank erosion; a = aeolian dust; and O = output of sediment from the lake in time Δt.

The sediment budget approach as traditionally applied has not met with universal acceptance because of at least four perceived damaging tendencies:

(i) it is claimed that it is a merely descriptive or accounting methodology;
(ii) the large error bands associated with measurements and calculations have encouraged a tendency to close the budget artificially;
(iii) the methodology has been applied primarily in a river basin context, and the importance of form changes on interfluves has been obscured;
(iv) there is a tendency for researchers to overlook the contribution of dissolved solids to the budget.

Nevertheless, this paper attempts to demonstrate the flexibility of a sediment budget methodology and the value of a step by step approach as advocated by Dietrich et al. (1982).

The steps that are followed in the following discussion are: an explicit recognition of the time scale of integration of the budget; a recognition and quantification of the major transport processes and storages of sediment and solutes; and the complicating role of biotic factors, weathering, stratigraphy, hydrologic pathways, and spatial scale effects.

TIME SCALE CONSIDERATIONS

The time scale used in sediment budgeting has a major influence on the conclusions drawn (Church, 1980). If, for example, we are using a million year integration, Holocene and contemporary sediment shifts cannot be resolved; if we use a 100-year integration or less, the products of Holocene and older sediment fluxes have to be interpreted as sediment storage sites. In other words the role and status of the components of the sediment budget change (Table 1). This observation has also been made in a qualitative way for the southern Coast Mountains of British Columbia (Ryder, 1981). We need to examine more carefully the selection of a time scale for the calculation of a sediment budget and the implications of the short and probably unrepresentative time available for data gathering.

The conceptual model (Fig. 2) attempts to identify the crucial but changing role of the storage sites and outputs in the sediment budget of a basin, such as that of the Lillooet River. Attention is directed to the major perturbations that distinguish

Table 1. Role and Status of Components of the Sediment Budget with Differing Time Scales of Integration

Budget components	> 10^6 years	10^4–10^6 years	10^2–10^4 years	< 10^2 years
Bedrock	Storage	Storage	Storage	Storage
Pleistocene sediments	Output	Storage	Storage	Storage
Holocene volcanics Paraglacial and neoglacial sediments	n/a	Output	Storage	Storage
Contemporary sediments	n/a	n/a	Output	Storage
Sediment yield	n/a	n/a	n/a	Output

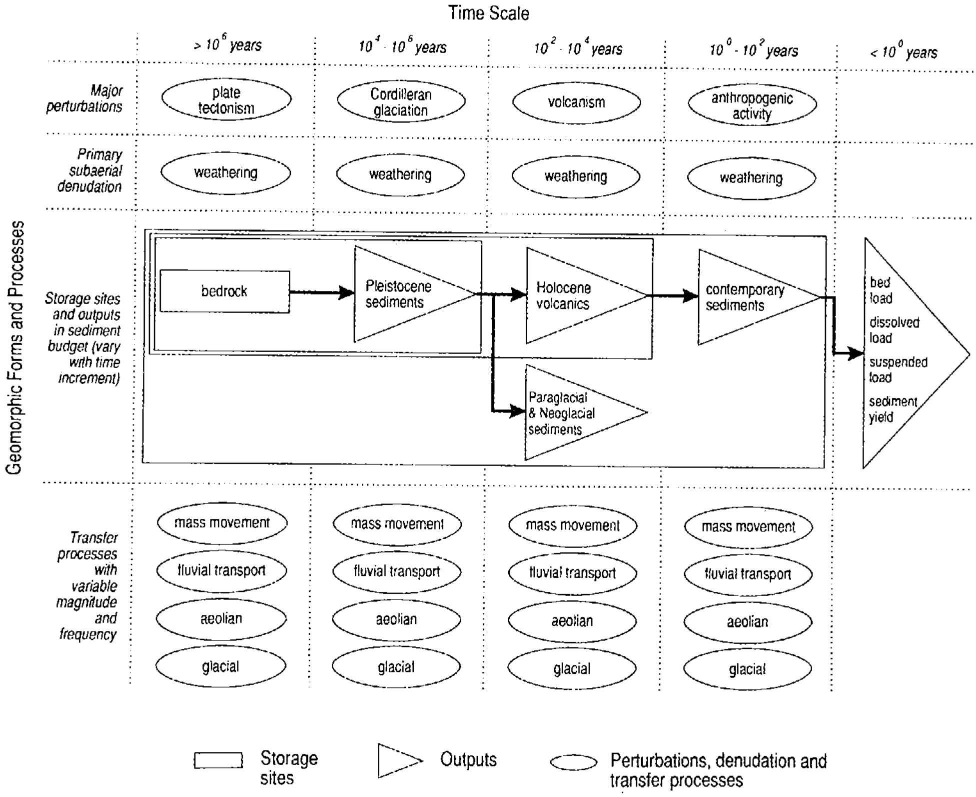

Fig. 2. A conceptual model of sediment storages and outputs over varying time scales in a glacierized, tectonically active mountain basin. The model is based on the Lillooet River basin.

each of the time scales, the comparative continuity of primary subaerial denudation (Slaymaker, 1977), and the enormous variability of the transfer processes (Wolman and Miller, 1960; Wolman and Gerson, 1978). It is with these considerations in mind that we can turn to the task of recognizing and quantifying the major transport processes in Holocene time (Fig. 3).

RECOGNITION AND QUANTIFICATION OF TRANSPORT PROCESSES IN HOLOCENE TIME

Soil Creep

It is assumed, though without confirmatory evidence, that soil creep operates on all slopes covered with unconsolidated regolith. Soil creep is a low magnitude, slow and almost continuously operating process that responds to gravitationally induced acceleration. The process moves a small amount of sediment from individual slopes, but it may be more effective on a basin-wide scale because of its ubiquity. If the slopes experiencing creep are not coupled with active river channels, the creep material will go into storage at the foot of the slope. Therefore, the amount of sediment exported by soil creep depends directly on drainage density, as well as creep rate and depth of moving regolith. Creep rate and depth of moving regolith typically average 2 to 5 mm a^{-1} over a depth of 0.5 to 1 m (Slaymaker and McPherson, 1977; Dietrich and Dunne, 1978; Roberts and Church, 1986), but drainage densities vary more widely (<1 km km^{-2} to >1000 km km^{-2}). In the Lillooet Basin measured drainage densities vary from 0.1 km km^{-2} to 1 km km^{-2}. If a drainage density of 1 km km^{-2} is used, a contribution of 1 to 3 × 10^4 m^3a^{-1} is provided by soil creep. This is only 1 to 3% of the contemporary sediment yield and equates to about 2 to 6 Bubnovs over the basin, where 1 Bubnov equals 1 mm of denudation of bedrock every 1,000 years. It is important to note that all sediment volumes are reported as bulk volumes, and in order to convert to solid rock volumes these bulk volumes are multiplied by 0.6.

Sackung

There are about 30 km of apparently actively sagging slopes undergoing deep rock creep in the basin. Although Bovis (1990) measured up to 100 mm a^{-1} in the Mount Meager volcanic complex, a more representative rate is probably 1 mm a^{-1} over an average depth of 100 m. Total sediment moved by sackung would then average 3 × 10^3 m^3a^{-1}, equal to 0.6 B.

Debris Flows

These are unquestionably the most important sediment sources in the Holocene and contemporary landscape. Jordan (1987) made an inventory of major debris flow channels in the Lillooet Basin using air photos at a scale of 1:50,000 and field checking. He identified a range of debris flow deposits from about 5,000 m^3 to

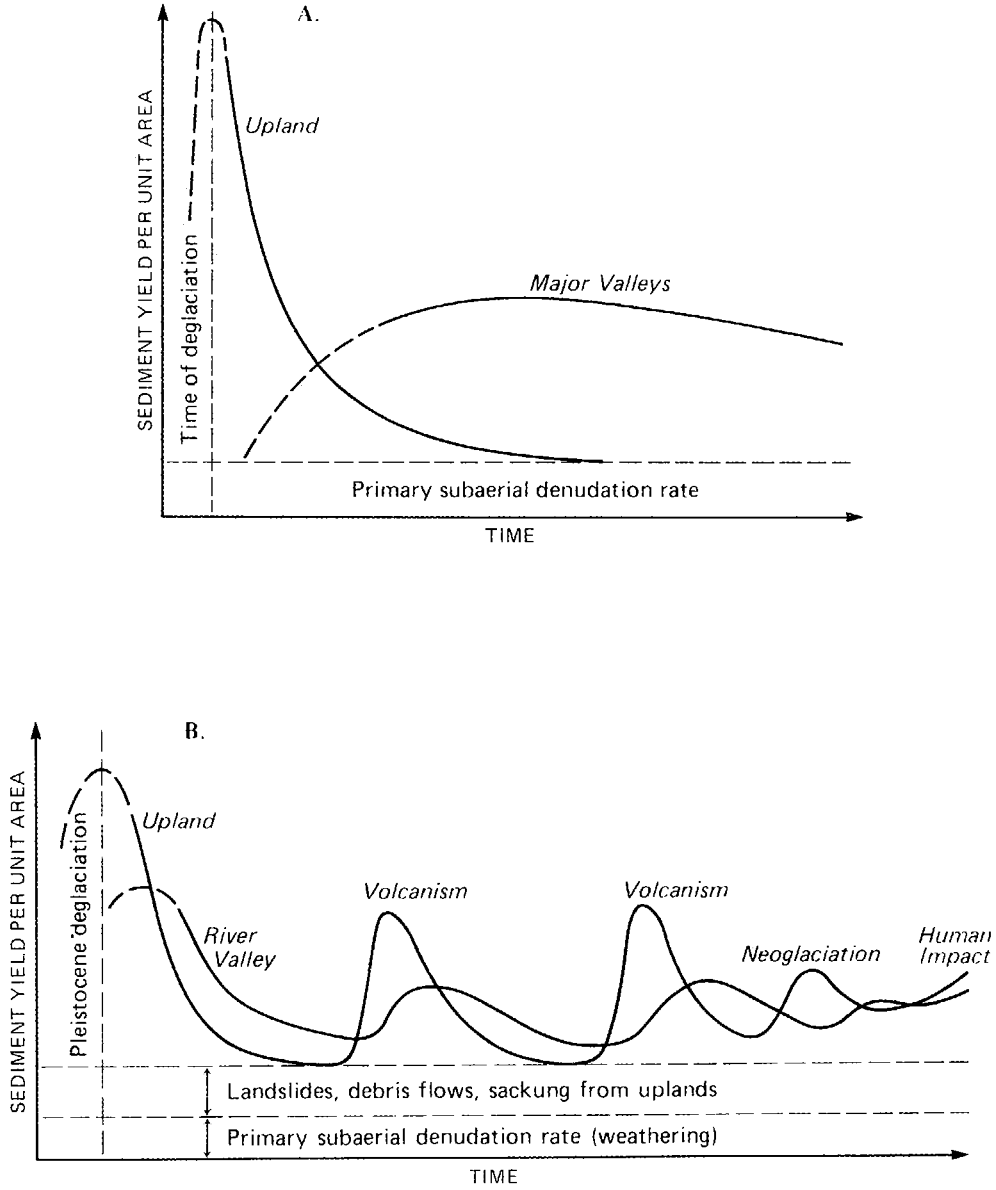

Fig. 3. The paraglacial sediment cycle (Church and Slaymaker, 1989)(a); and a model of Holocene sedimentation in Lillooet River Valley (Jordan and Slaymaker, 1991)(b).

larger than 100,000 m^3. For ease of calculation he estimated from historical and morphological evidence that "small" debris flows yielded an average of 20,000 m^3 every 10 years, 25% of which was delivered to the channel; "large" debris flows yielded an average of 50,000 m^3 every 10 years, with a similar proportion stored. The average contribution was 143 to 427 $\times 10^3$ m^3a^{-1} or 28 to 82 B. The unsolved problem was how to deal with smaller debris flows and especially debris torrents that left no morphological evidence. It is probable that this is the most serious omission in his calculation. Evidence from adjacent basins suggests that debris torrents delivering less than 5,000 m^3 have occurred historically in 27 of the 89 creeks examined in the Boston Bar Creek valley (Slaymaker, 1990), as compared with 13 delivering more than 5,000 m^3. This represents approximately one-quarter of the total volume of sediment delivered by all debris torrents in the historical period. In the sediment budget calculated by Jordan and Slaymaker (1991), the omission of these smaller debris torrents and flows could therefore amount to as much as 105 m^3 a^{-1} or 20 B.

Landslides

Large landslides, generating more than 500,000 m^3 of sediment, are a significant sediment source, especially in the Mount Meager Volcanic Complex. Nine major events were identified together with dates of occurrence, one dated as early as 4,000 years B.P. The amount of sediment stored and the amount removed by river action were estimated from the volume of river incision. Even though sediment delivery from this source is highly episodic, estimates averaged over 100 years and 5,000 years, respectively, produced similar volumes of 3 to 11 $\times 10^4$ m^3 a^{-1} or 6 to 20 B.

Smaller landslides, containing less than 500,000 m^3 of sediment, have not been included in the budget. Because of their infrequency of occurrence, small landslides are not such significant independent contributors to the sediment budget as are debris flows, and many of the smaller landslides are incorporated into or transformed into larger debris flows (Pearce and Watson, 1983).

Glaciers

Contribution by glaciers, which cover 16% of the basin, has been estimated at 13 to 36 B from field instrumented sites (Slaymaker, 1977), but these sites were located below proglacial lakes. The average for the basin was set at 20 to 100 B (Eyles et al., 1982). This is likely an overestimate as many of the glaciers in the basin drain into small lakes.

Bank Erosion

Evidence of fluvial incision into bedrock or Pleistocene glacial materials in the main valley is largely confined to aggradational Holocene sediments. It is therefore concluded that the net effect of bank erosion is negligible, by contrast with the regional pattern for British Columbia (Slaymaker and McPherson, 1977; Church and Slaymaker, 1989).

Slope Erosion

Slope erosion by surface wash, rilling and gullying, subsurface eluviation, and piping is not well understood in this basin. High rates of surface wash have been documented on bare morainic slopes, in localized areas above timberline (Jones, 1982), and in logged and cultivated areas. Subsurface eluviation is important in generating enhanced solute concentration in permanently saturated zones. It is estimated that 5 to 26 × 103 m^3 a^{-1} of sediment, equivalent to 1 to 5 B, is produced by these processes (Gallie and Slaymaker, 1985).

Solution

Of the 417 B of mean denudation in the basin (Jordan and Slaymaker, 1991), approximately 73 B are accounted for by solution. This large absolute amount of solution is a function of high discharge intensity, highly weatherable volcanics, and the high clastic sediment load.

Fluvial Clastic Sediment Yield

The long-term mean clastic sediment yield for Lillooet River basin is 344 B and the mean total yield (including the dissolved component) is 417 B (1913 to 1986). Based on variation in the rate of Lillooet delta advance as interpreted from sequential air photography, the clastic component of yield has varied from 203 to 578 B (Gilbert, 1975; Jordan and Slaymaker, 1991) (Table 2).

It is clear that if the sediment budget were balanced, the supply of sediment from the slopes should equal the sum of valley aggradation and delta growth. Table 2 shows that there is a severe imbalance in the sediment budget. During the period of minimum yield (1913 to 1948), the highly improbable combination of minimum aggradation and maximum material supply would still leave a 25% deficit of sediment supply. If we accept the mean value of each of the three terms of the budget, the material supplied from the slopes accounts for only 40% of that required for a balanced budget. This finding implies that the sediment budget is radically unbalanced, and we are forced to consider the response and recovery time of the basin to historic and geologic events as well as to reevaluate the reliability of the measurements made. The remainder of the paper considers ways in which basin response and recovery time can be analyzed through a fuller exploration of the unbalanced sediment budget.

RECOGNITION AND QUANTIFICATION OF STORAGE ELEMENTS AND SOLUTE SINKS IN CONTEMPORARY TIME

In this section we consider the variable residence time of both sediments and solutes in sinks and storage sites over contemporary time ($<10^2$ years) (Meade, 1982). The value and limitations of reservoir theory were discussed by Dietrich et al. (1982) though only in relation to sediment flux (Madej, 1989). In the case of solutes, a different relationship obtains for individual ionic species as, for example,

Table 2. The Unbalanced Sediment Budget[a]

Material from slopes

	Range	Mean
Large debris flows	28–82	55
Small debris flows	7–21	14
Landslides	6–20	13
Glaciers	19–97	58
Soil creep	2–6	4
Sackung	0.4–0.8	0.6
Slope erosion	1–5	3
Solution	70–76	73
	134–308	221

Material in valley bottom

Aggregation		Yield	
Range	Mean	Range	Mean
95–190	142	273[b]–654[c]	417[d]

[a] All values in Bubnovs—one Bubnov is equivalent to 5.2×10^3 m^3 a^{-1} of bulk sediment volume for the Lillooet Basin. To convert to equivalent solid rock volumes, the bulk volumes should be multiplied by 0.6.

[b] Average yield (1913–1948)

[c] Average yield (1948–1969)

[d] Average yield (1913–1986)

chloride moves through soils and biomass with minimal delay; potassium, calcium, and sulfate experience preferential uptake by biomass; and the primary nutrients phosphorus and nitrogen experience differential uptake by soils.

Aeolian fallout is an interesting case study. The regional or allochthonous rate of aeolian fallout is calculated as 11 g m^{-2}a^{-1}. This rate of contemporary aeolian dust fallout agrees well with the annual input to the Green Lakes valley in the Colorado Rocky Mountains, estimated at 14 g m^{-2} (Caine, 1986), and that calculated for the Polish Tatra Mountains, between 1 and 265 g m^{-2} (Izmailow, 1984).

The bedrock in the Lillooet River basin is discontinuously covered by a stony dioritic Pleistocene till. This, in turn, is overlain by fine-textured Holocene loess deposits, including two tephra layers of which the lower is derived from Mount Mazama and the upper from Bridge River. Consequently, it is possible to calculate the magnitude of aeolian deposition over the post-glacial period from the accumulation of aeolian material in the soil profiles. A regional estimate of aeolian accumulation is 20 cm. When account is taken of the tephra layers, organic matter content, gravel and boulders, about 6 cm can be ascribed to wind deposition, and this converts to an average accumulation of about 6.3 g $m^{-2}a^{-1}$.

Not only does aeolian accumulation represent a sediment sink, but its occurrence in depressions close to ridge tops leads to very low rates of denudation at a number of sites above timberline (Jones, 1982; Souch, 1986; Owens and Slaymaker, 1993). Not only are some of these alpine basins decoupled from the lower part of the Lillooet basin in the same sense as that described by Caine and Swanson (1989), but they are experiencing net sediment accumulation on the upper slopes as well as at the footslopes.

IDENTIFICATION OF LINKAGES AMONG SEDIMENT AND SOLUTE TRANSPORT PROCESSES AND STORAGE ELEMENTS AND/OR PATHWAYS OF SOLUTE MOVEMENT

Identification of linkages is critical in distinguishing those erosion processes that are separate additive components of sediment discharge from those that are carrying the same material along sequential parts of one long sediment pathway (e.g., weathering, soil creep, and bank erosion are not cumulative and may involve entirely the same material).

With respect to solutes, the watershed can be viewed as a series of hydrologic reservoirs through which the solutes can be routed. Solute export is a function of (a) the number and type of hydrologic reservoirs, (b) the net chemical reactivity, and (c) the volume and flow rate of water within each reservoir (Jackson et al., 1978; Gallie and Slaymaker 1984, 1985).

The net effect of linkages among the processes is that material supply from Lillooet River basin slopes is overestimated. Hence, the failure of the sediment budget to balance is even more pronounced than Table 2 suggests.

THE ROLE OF BIOTIC FACTORS

Organic matter may make up a large proportion of sediment in transport, thus potentially complicating sediment sampling and confounding interpretation of the data (Swanson et al., 1982). Interactions between dissolved and fine particulate organic and inorganic matter present problems for sampling, distinguishing, and interpreting dissolved and suspended sediment yield from a sediment-routing standpoint. These interactions affect the fate and persistence of pollutants in ecosystems.

Plants and animals also affect soil and sediment movement and temporary storage in a variety of ways. Large woody debris in streams and on hillslopes and tree roots retain sediment at temporary storage sites. The multiple, cumulative effects of vegetation on sediment routing through small (less than 100 ha) drainage basins have been demonstrated by studies in both forested and disturbed conditions (Hogan, 1987). The role of marmots and grizzly bears in soil surface disturbance is locally important. Biomass is integral to nutrient cycling. If gross primary productivity, net primary productivity, and living and dead biomass accretion data are not available, then the assumption that biomass solute input equals biomass solute output is commonly made for forest ecosystems. However, this is clearly an inadmissible assumption for ecosystems that are in process of change, either aggrading or degrading. The net effect of biotic factors in the Lillooet River basin is towards overestimating the total denudational activity both on the slopes and in the valley bottom.

THE ROLE OF WEATHERING

Study of weathering and its effect on availability of plant nutrients, soil development, and soil stratigraphy is advanced compared with knowledge of weathering as a regulator of sediment routing. Weathering affects the availability of material for transport and the types and rates of transport processes operating in an area. Geological material enters the sediment-routing system by weathering of bedrock, which makes it available for transport. Dietrich and Dunne (1978) suggested that weathering is a critical rate-limiting factor in the long-term movement of sediment in many mountain environments. This may be particularly true in steeplands with shallow soils over competent bedrock, such as the Lillooet River basin. The understanding of contemporary and past weathering rates in the British Columbia Coast Mountains will greatly assist in the interpretation of sediment budget responses over time (Slaymaker, 1988).

INTERPRETATION OF STRATIGRAPHY

Soil stratigraphy (the use of surface and buried soils to subdivide and to correlate sediments primarily of Quaternary age) may be useful in constructing sediment budgets by identifying the relative stability of different landscape elements and by placing limits on frequency and rate of erosion (Hilton-Johnson, 1982). Easily reversible properties, such as pH, organic material, carbonates, and others, are probably in equilibrium with existing climatic and vegetation conditions at a site, but irreversible properties, such as plinthite, oxic horizons, duripan, and others, may persist under conditions that are drastically different from those under which they developed (Yaalon, 1971).

Soil stratigraphy may be used to identify relative contributions of different landscape units to the overall sediment yield from a drainage basin. Low erosion rates on hillslopes and ridges are indicated by soils displaying strongly developed profiles and by clay mineralogy and pollen reflecting climatic and vegetation conditions that have not existed for tens or even hundreds of thousands of years. In contrast, hillslopes bearing weakly developed soil profiles or active colluvium indicate more rapid erosion rates. Another potential use of soil stratigraphy in studying erosion processes is an indicator of recurrence intervals of episodic erosion events. Different ages of landslide episodes can often be recognized by differences in soil depth and weathering intensity, or by buried soil horizons.

Paleoenvironmental reconstruction based on the lacustrine sedimentary record suggests that there have been changes in both the climate and the timberline over the post-glacial period, with both the xerothermic interval and Neoglacial conditions identified. Consequently, even though the order of magnitude of aeolian deposition over the post-glacial period is similar to the contemporary figure, fallout rates are likely to have varied over the longer period in association with changes in climate and catchment conditions. The analysis of the stratigraphy of the soil profiles in the Goat Meadows catchment indicates that there has been an increase in the rate of aeolian deposition over the second half of the Holocene Epoch (Souch, 1989).

EVALUATION OF THE HYDROLOGIC BALANCE

Whereas in the construction of a sediment budget a determination of surface runoff is all that is required with respect to hydrology, in the construction of solute budgets all components of the hydrologic balance must be evaluated in the form

$$P + SM + GM = Q + ET + \Delta S \ldots, \tag{4}$$

where P is precipitation, SM is snowmelt, GM is glacier melt, Q is runoff, ET is evapotranspiration, and ΔS is change in storage in soil and bedrock (Zeman and Slaymaker, 1978. The most difficult component to evaluate in a solute budget context is ΔS, especially in light of the variety of subsurface pathways followed by the solutes (Gallie and Slaymaker, 1985).

Spatial Scale Considerations

Basins and regional units of different sizes in British Columbia permit an assessment of the aggregate effects of the various processes discussed above on sediment budgets. The following section therefore reviews results from local studies of whole basins and regions.

Small Lake Basins

Late Holocene sediment yields for three small lake basins that straddle the alpine-subalpine ecotone in the Lillooet River basin show an increase in yield with a decrease in elevation. This observation emphasizes the importance of storage effects on sediment availability (Owens and Slaymaker, 1993). Field measurements of the operation of contemporary individual geomorphic processes in these basins, when integrated over the whole catchment, account for significantly more sediment flux than lake sediment-based sediment yield (Souch and Slaymaker, 1986). These basins have a stream subsystem that is decoupled from the hillslope subsystem, with material eroded from the hillslopes going into storage. Such a phenomenon also has been suggested for catchments above the timberline in the Colorado Front Range (Bovis and Thorn, 1981; Caine and Swanson, 1989), the central Pyrenees in Spain (Diez et al., 1988) and the Polish Tatra Mountains (Kotarba et al., 1987). In two of the basins, which have steeper slopes and a greater relative relief (260 m and 226 m, respectively, compared to ca. 50 m for the third basin), the fluvial and hillslope subsystems are periodically linked by episodic large-scale mass movements such as debris flows and rock avalanches (Jordan and Slaymaker, 1991).

The specific sediment yields for the three catchments studied are orders of magnitude lower than regional rates for larger catchments (Walling, 1983). Contemporary sediment and solute yields and transfers consist of at least two components:

(i) primary denudation of bedrock;
(ii) gain or loss of sediment (and solutes) due to storage effects.

Consequently, in British Columbia and other similar environments, specific sediment yield will not equate with primary denudation of the land surface at any spatial scale, though it will tend asymptotically towards that value as basin size decreases.

Debris Torrent Basins

Basins between 0.1 and 10 km^2 in area in southwestern coastal British Columbia are dominated by debris torrent activity (Van Dine, 1985). The question has been asked whether their incidence has increased in response to climate change. Analysis of the sediments stored in debris torrent fans indicates that most of Holocene time (ca. 10,000 years) has been influenced by active debris torrents (Slaymaker, 1990). Storage controls the magnitude and frequency of occurrence of debris torrents in the sense that if there is little sediment stored in the basin, little debris torrent activity will occur even under the most extreme and intense rainfall events.

Large River Basins

Semi-quantitative budget estimates for Lillooet River basin (3,150 km^2) and qualitative estimates for Fraser River basin (230,000 km^2) have been made (Jordan and Slaymaker, 1991; Slaymaker, 1991). Rate of aggradation of flood plains and growth of deltas are substantially greater than the rate of supply of sediment from adjacent slopes and tributary systems—that is, sediment storage from the past is influencing current yields. A qualitative sediment budget analysis of the Fraser River basin emphasizes the importance of time scale and variations in the degree of connectivity of the basin in any consideration of management of the basin or its constituent parts.

Regional Analysis

Sediment yield considerations for the whole of British Columbia (Slaymaker, 1987; Church and Slaymaker, 1989) suggest that sediment systems in glaciated British Columbia are dominated by events of the late to immediate post-glacial period. (Fig. 3a). This disequilibrium is defined as a transient relationship between input and output of sediment. Interest focuses on identifying the nature and extent of this transient response. In the case of Lillooet River basin, a number of perturbations have been identified and each of these perturbations has produced a transient response (Fig. 3b). Interpretation of the geomorphology of this region via the sediment budget approach requires careful consideration of the full range of past and contemporary processes.

CONCLUSION

The sediment budget, even if only partially understood for a region of the size of the Lillooet River drainage basin or larger, provides a framework for examining both functional and historical geomorphology, and for linking geomorphic synthesis and analysis. In this role, the sediment budget may well encourage the "reenchantment of geomorphology" (Baker and Twidale, 1992).

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