European Geosciences Union
General Assembly 2012

LATE QUATERNARY STREAM INCISION RATES DUE TO TECTONIC UPLIFT IN NORTH PELOPONNESE, GREECE

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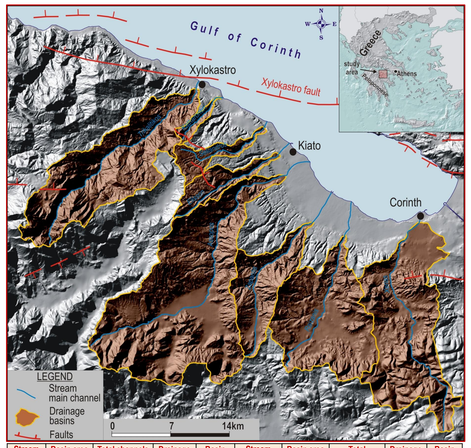
1. Introduction

The landscape in actively deforming areas results from interactions among the processes of uplift or subsidence and consequent surface processes that can lead to local erosion or deposition (Seong et al., 2008). It is often useful to try to calibrate the rates and relative contributions of each process at a particular time or over some span of time. In tectonically active settings, characterized by long-term uplift, river incision rates are strongly dependent on the rates of uplift. The morphology of the landscape can provide insights into the interactions of surface processes and uplift.

This study focuses on defining rates of fluvial incision for the last 330 ka along valley systems of eight streams (Trikalitikos, Katharoneri, Seliandros, Elisson, Assopos, Zapantis, Raizanis and Xerias) that drain the eastern part of the tectonically uplifting area of north Peloponnese. The paper also explores the relationship between tectonic and surface erosional processes along these streams.

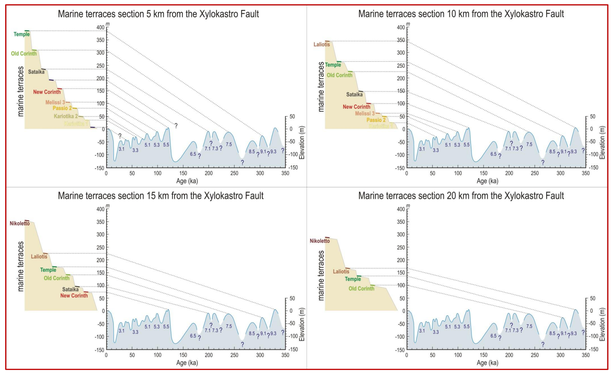


Stream	Basin area (km2)	Total channels length (km)	Drainage Density	Basin slope (%)	Stream	Basin area (km2)	Total channels length (km)	Drainage Density	Basin slope (%)
Xerias	164.7	341.5	2.07	25	Elisson	27.95	77.23	2.76	35
Raizanis	135.6	299.4	2.21	25	Seliandros	21.47	53.94	2.51	29
Zapantis	66.47	190.5	2.87	33	Katharoneri	14.69	44.11	3.00	44
Assopos	268.4	555.5	2.07	32	Trikalitikos	139.0	403.20	2.90	44

Digital Elevation Model of the drainage basins of the studied streams. The table includes the characteristics of the streams and their basins.

2 . Study area

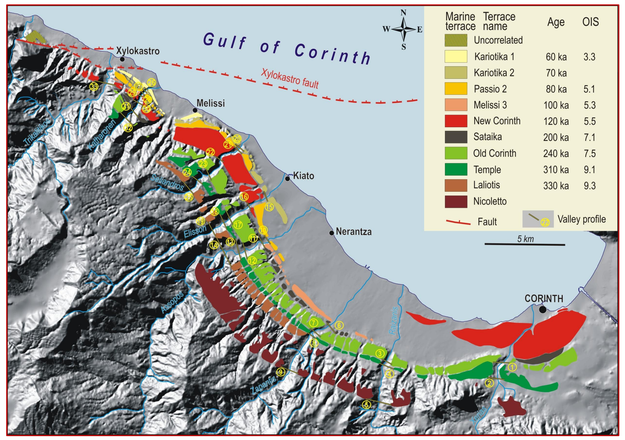
The studied rivers have a S.SW – N.NE flow direction and discharge into the Gulf of Corinth along the coastline between the cities of Corinth and Xylokastro. They are developed on the uplifted block of the offshore extension of the Xylokastro normal fault which is one of the main south bounding faults of the Gulf of Corinth (the Corinth rift). Gulf of Corinth is an N 100º E oriented elongated asymmetric graben, 150 km long, characterized by high levels of seismicity and high extension rates, separating the Peloponnese from continental Greece (Rigo et al., 1996). It is bounded by systems of active roughly E-W trending normal faults, located mainly along the southern coast, intersecting the structure of the Hellenides at almost right angles. Active faulting on the southern side of the gulf has resulted in more than 950 m of Pleistocene uplift of the mountains in the south where the study area is located.



Correlation of palaeo-shorelines in space and time. The elevation of palaeo-shorelines at four sections at different distances from the Xylokastro fault (5, 10, 15 and 20 km) are correlated with the sea-level highstrands. (modified from Armijo et al., 1996).

3. Marine terraces

A series of ten uplifted marine terraces ranging in elevation from 10 to 400 m, which lie on the hanging wall of the above mentioned Xylokastro normal fault, have been recognized, mapped in detail and correlated with Late Pleistocene oxygen-isotope stages of high sea-level stands and with global sea-level fluctuations (Armijo et al., 1996). The lower reaches of the study *streams cut* down through these marine terraces. The uplifted Late Pleistocene marine terraces of known age were used as reference surfaces in order to determine fluvial incision rates for the last 330 kyrs.



Digital Elevation Model of the broader area of the deformed marine terraces between Corinth and Xylokastro. The locations of the cross-valley profiles are also indicated. DEM is produced by topographic maps at the scale of 1:50,000. Marine terraces and faults are based on Armijo et al. (1996).

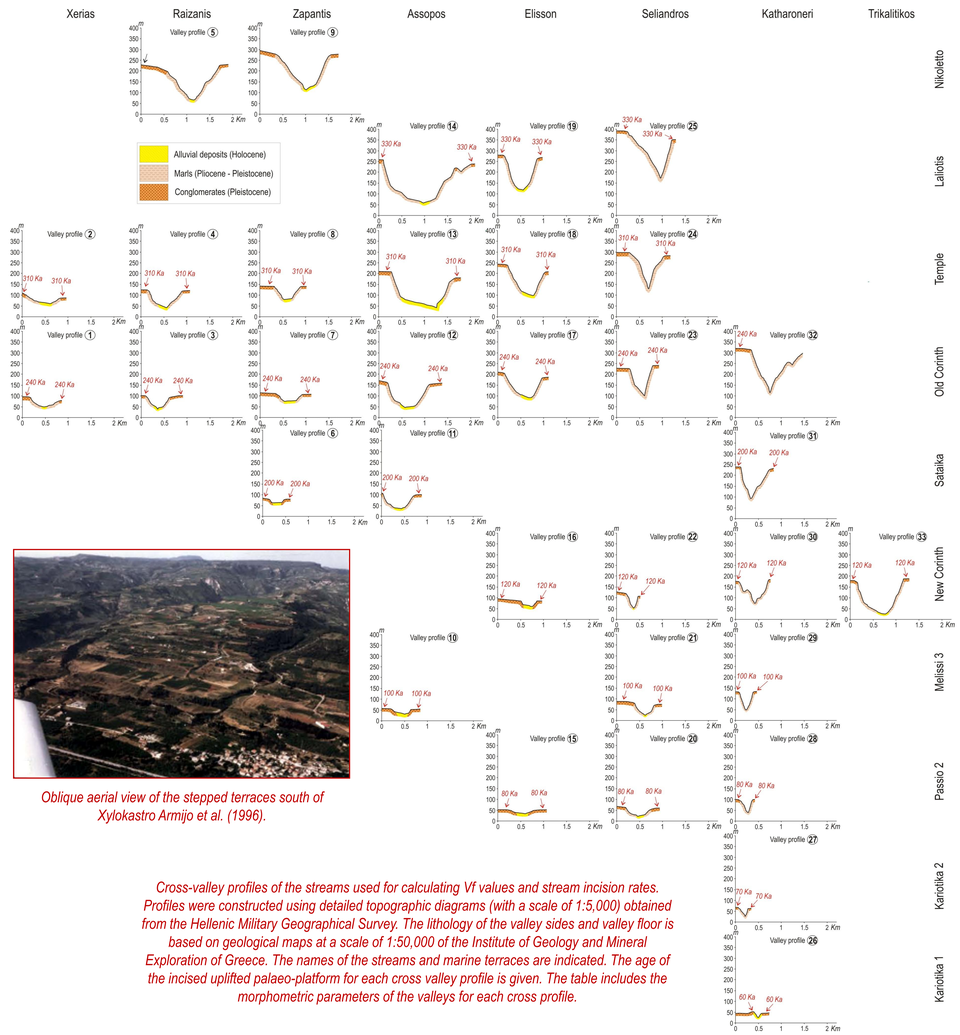
4. Methodology

To evaluate the incision rates on the uplifted block of the Xylokastro fault thirty-three topographic cross sections were constructed perpendicular to the valleys at specific locations where streams cut down the marine terraces. The sections were drawn through fieldwork measurements as well as using a digital elevation model (DEM) produced by detailed topographic diagrams at the scale of 1:5,000. Cross sections were constructed as close as possible to the inner edges of the marine terraces because these points correspond precisely to the age of the palaeo-shoreline during the interglacial stage. These marine platforms allow the reconstruction of the geometry and age of the former (prior the formation of the valley) surface that represents the hypothesized topography in the absence of erosion so bedrock incision rates can be directly calculated. In order to evaluate the incision rates and the effect of the Xylokastro normal fault on valley geometries various morphometric characteristics of the valleys were measured/calculated from the cross-valley profiles of thirty-three locations along the main stream channels. These indices include the width (Vw) and the height (Vh) of the valley, the ratio of valley width and valley high (Vw/Vh), the width of valley floor (Vf), the elevations of the valley floor (Esc) as well as of the left and right divides (Eld, (Erd), and the ratio of valley floor width to valley height (Vf)). Vf is a useful parameter that helps to define V-shaped deep valleys of actively incising stream which may be associated with rapid uplift (Bull & McFadden, 1977). It was calculated using the following formula:

$$Vf = Vfw/[(Eld-Esc)+(Erd-Esc)/2]$$

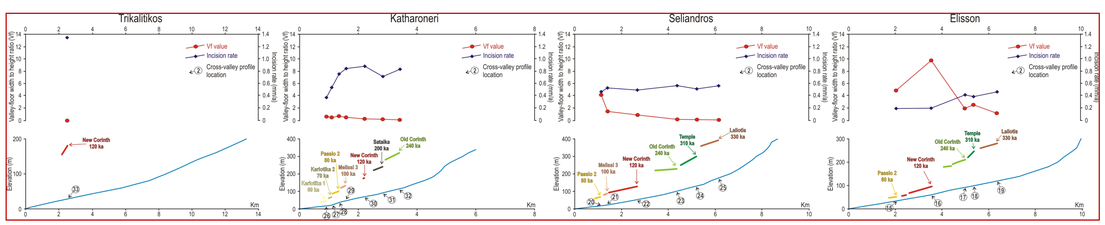
Vfw = the width of valley floor,
Eld = the elevation of the left drainage divide,
Erd = the elevation of the right drainage divide and
Esc = the elevation of the valley floor

Stream incision is the change in elevation between the inner edge of the marine terrace and modern stream channel level. Since the date of each marine platform abandonment is known, the stream incision rates were measured. The mean incision rate of each stream for the last 330 ka was estimated and both spatial and temporal variations of incision rates along the reaches of the studied streams were reconstructed. Additionally the longitudinal profiles of main stream channels were constructed and analyzed in order to investigate the response of the study streams to the tectonic uplift.

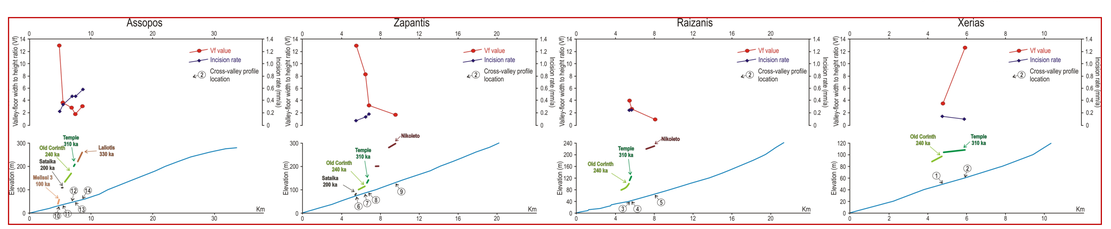


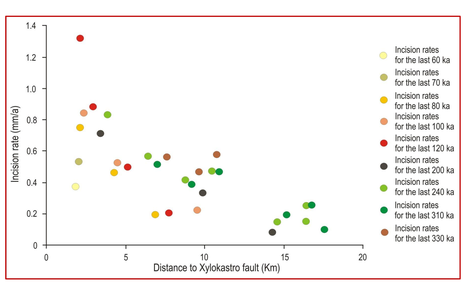
Cross-valley profiles of the streams used for calculating Vf values and stream incision rates. Profiles were constructed using detailed topographic diagrams (with a scale of 1:5,000) obtained from the Hellenic Military Geographical Survey. The lithology of the valley sides and valley floor is based on geological maps at a scale of 1:50,000 of the Institute of Geology and Mineral Exploration of Greece. The names of the streams and marine terraces are indicated. The age of the incised uplifted palaeo-platform for each cross valley profile is given. The table includes the morphometric parameters of the valleys for each cross profile.

Oblique aerial view of the stepped terraces south of Xylokastro Armijo et al. (1996).



Longitudinal profiles of the modern stream beds and marine terraces profiles along the west bank of the stream channels. The name and the age of each marine terrace are given. Arrows indicate the inner edges of the marine terraces. Numbers in circles correspond to the locations of the cross-valley profiles. Diagrams show the ratio of valley floor width to valley height, and fluvial incision rates for the streams plotted along the longitudinal profiles.





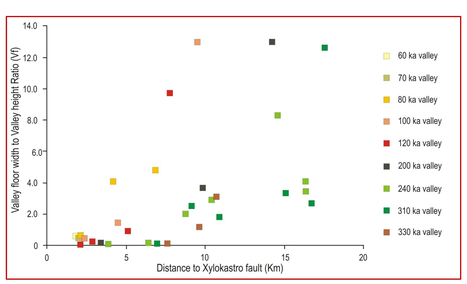
Plot of incision rates along the studied streams as a function of distance from the Xylokastro fault trace.

5. Results

Valley form and fluvial incision rates are dependent on bedrock lithology, tectonics and surface process dynamics. All cross-valley profiles were constructed at locations consisting of the same lithology (marls of Pleiocene-Pleistocene age, capped by relatively resistant to erosion conglomerates which correspond to the surfaces of the marine terraces). Consequently, for all eight studied streams bedrock lithology affects valley morphology and stream incision in a similar way.

Vf values range between 0.01 and 13 and vary significantly between different locations. High values were observed at the lower reaches of the streams, whereas lower values resulted from the incised reaches of the streams especially at their paths through the older and higher marine terraces. Very low Vf values (<1) were estimated for the streams of Trikalitikos, Katharoneri and Seliandros which drain the western part of the study area and are closer to the Xylokastro fault. On the other hand streams of the eastern part (which are located far from the fault) are characterized by significantly higher Vf values.

The calculated fluvial incision rates range from 0.1 to 1.3 mm/a and seems to lessen with distance downstream since older - higher – marine terraces include the accumulated tectonic uplift of several events that formed newer lower terraces. Stream incision rates are strongly controlled by the distance of the stream valleys from the active normal fault of Xylokastro. Higher rates are observed for the Trikalitikos, Katharoneri, Seliandros, Elisson and Assopos whereas lower incision rates were estimated for the eastern streams (Zapantis Raizanis and Xerias). The estimated incision rates along the main stream channels of Seliandros, Elisson Raizanis and Zapantis suggest a long-term stability of river incision rates over the last 330-310 ka. On the other hand, incision rates for Katharoneri and Assopos show variations through time with a significant lowering for the last 100 ka and 330 ka respectively. A possible reason for this is the presence of more resistant to fluvial erosion formations along the lower reaches of these streams or variations in the thickness of the hard caprock .



Plot of ratio of valley floor width to valley height (Vf) as a function of distance from the Xylokastro fault trace

6. Concluding Remarks

The geomorphic evolution of the studied streams has been affected by the lithology of the bedrock, the tectonic uplift of the area, sea level fluctuations during the Late Quaternary and the head-ward erosion and incision of the channels.

The spatial distribution of Vf ratio values and stream incision rates are strongly controlled by the distance of the stream valleys from the active fault of Xylokastro. Valley floor width to valley height ratios (Vf) and incision rates were found to differ in magnitude between different locations. Lower Vf values and higher incision rates were estimated for the streams of the western part of the study area. This is the consequence of rapid downcutting resulting from higher rates of tectonic uplift since these streams drain an area closer to the Xylokastro normal fault trace. Stream downcutting is keeping pace with the drop in base level. The highest incision rate (1.33 mm/a for the last 120 ka) and lower Vf value (0.01) was estimated for the westernmost stream (Trikalitikos) while the lower incision rate value (0.1 mm/a for the last 310 ka) was calculated for Xerias Stream which is located about 17 km far from the fault.

The estimated incision rates through time are comparable with the component of regional uplift and with the slip rate of the Xylokastro fault (maximum uplift rate of 1.3 mm/a according to Armijo et al. (1996) over the last 350 ka.

References

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