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Convenors: C.R. THORNE (*) & P. BILLI (**)

COLIN R. THORNE

REVIEW OF FLUVIAL GEOMORPHOLOGY 1993-1998

1. INTRODUCTION

This paper summarises the content of an address made by the author while chairing the session on Fluvial Geomorphology at the International Geomorphology Conference at Bologna, Italy in August 1997. While the paper attempts to present an overview of significant progress in the study of fluvial geomorphology since the previous IGC at Hamilton, Canada in 1993, specific papers and individual researchers are not mentioned by name due to the impossibility of covering all significant contributors in a short address and paper. The number of useful contributions is such that, if particular authors and their contributions were named, there would inevitably be unjustifiable errors of omission. The author was greatly assisted in the preparation of the address by the helpful advice and inputs of the individuals listed in the Acknowledgments.

2. RECENT RESEARCH PROGRESS

A great deal of research progress has been made in the field of fluvial geomorphology in the last five years. This section highlights some of the most significant areas of progress. The topics are not listed in order of decreasing or increasing importance, but follow a logical, process-based sequence from the detailed study of flow and sediment processes, to the short and long-term morphological channel changes driven by those processes, the role of previously under-researched factors such as riparian vegetation and the applic ation of research fndings in river management and engineering. The section concludes by considering recent theoretical and philosophical developments which underpin the study of fluvial geomorphology and which will provide the framework for further progress.

2.1 *Flow Dynamics*

The development of new and innovative instruments such as the Acoustic Doppler Current Profiler (ADCP) and Acoustic Doppler Velocimeter (ADV) has enabled geomorphologists to make significant progress in the measurement and explanation of the three-dimensional fluid flow fields found in open channels. Field measurements, especially when coupled with the use of Differential GPS for accurate position fixing, have begun to revolutionise our understanding of velocity distributions and fluid pathways in natural rivers with complex geometries. The capability to work in rivers much larger than those investigated in the past has extended the scale of measurements to a degree unimaginable even a few years ago and means that process geomorphologists are no longer restricted to dealing only with creeks and small rivers.

Progress has also been made in flume studies, particularly in the study of phenomena that are difficult to observe in the field, such as the inter-actions between channel and floodplain flows during overbank events. Original research and publications concerning fluid turbulence and the nature of coherent flow structures in meandering and braided rivers are beginning to clarify links between macro-, meso- and micro-scale fluid processes that have long been suspected, but never before demonstrated.

Continuing growth in the computational power and available memory of computers has enabled the development of finite element methods and Computational Fluid Dynamics for 2 and 3 dimensional modelling of open channel flows. Another major development is that modern computers are now able to display the outputs of models

(*) *Department of Geography, University of Nottingham, Nottingham NG7 7RD, UK.*
(**) *Dipartimento di Scienze Geologiche e Paleontologiche dell'Università di Ferrara, corso Ercole I d'Este, 44100 Ferrara, Italy.*

as perspective views of the channel, with flow paths visualised using vector arrows and channel changes through time simulated using video loops. These outputs are a quantum leap ahead of the impenetrable tables of densely-packed numbers hitherto produced by computer models and they allow the outputs of these models, for the first time, to be fully appraised and evaluated by fluvial geomorphologists who are not themselves mathematical modellers.

While good progress has been made in linking models of the channel hydraulics to sediment dynamics, much remains to be done before any existing code can truly be regarded as being a «morphological» model, that is one capable of accounting for the complex interactions between fluid flow, sediment movement and morphological channel changes over anything but the shortest timespans. It is still true today that a modeller using a relatively simple model, but with an intimate knowledge of the fluvial geomorphology of the river in question, will produce more reliable morphological predictions than a less knowledgable modeller armed with even the most sophisticated computer code.

2.2 Sediment Dynamics

Steady progress has continued during the last five years concerning studies of the mechanics of sediment movement in rivers. Perhaps the most spectacular advances have been made concerning the entrainment and transport of mixed grain sizes in gravel and cobble-bed streams. Through long-term field studies at instrumented sites and meticulous flume studies using carefully graded sediments, insights have been gained that help to resolve the remaining issues surrounding the near-bed processes controlling the mobility of grains of various sizes within a widely graded mixture. The improved understanding of selective entrainment and transport that has resulted appears finally to explain phenomena such as the occurrence of pebble-clusters, the pulsing of bedload, the downstream fining of sediments in gravel-bed streams and the abrupt gravel to sand transition that is observed along the bed profiles of many rivers.

However, it would be incorrect to conclude that recent research progress has been restricted to the dynamics of coarse particles. Important work has also been performed on the movement and storage of fine-grained sediments, particularly in applying new dating and tracing techniques to quantifying rates and patterns of floodplain sediment accumulation. The findings, for example using Caesium-137 dating of recent floodplain deposits, demonstrate that the depositionary processes and resulting sediment distributions are strongly linked to subtle, but significant features of floodplain terrain, and that floodplain flows and floodplain sediment dynamics are much more complex than was previously recognised.

2.3 Channel Morphology and Morphological Changes

In the 1960s, 70s and 80s the vast majority of research projects were conducted on meandering rivers, but in the 1990s greater attention has been given to multi-threaded watercourses. Fundamental to the study of multi-channel systems has been the establishment of a clear understanding of the differences between braided and anastomosed rivers. This is significant not only for stream classification, but also because our inability to differentiate between high and low energy multi-channel patterns in the past had obscured significant differences in the process-form relations that controlled morphological evolution in these contrasting fluvial environments.

The theory of braided river morphology has clearly been advanced through the development of models capable of simulating the patterns of planform evolution characteristic of braided systems. Empirical research has supplied useful new information and data sets gathered in projects ranging from direct measurements of flow and sediment dynamics in some very large rivers, to carefully formulated experiments using scale-model channels in the laboratory.

Remotely-sensed data are now used routinely to study morphological change at a wide variety of scales. Ground level, digital photography has replaced the erosion pin as the preferred method of monitoring surficial erosion and bank retreat and, when linked to a digital terrain model, calculating volumetric rates of erosion or sediment accumulation. Improvements in photogrammetric and image processing technologies for aerial photographs and satellite images suggest that quantitative analysis of reach and system-scale morphological changes based entirely on remotely-sensed data is not far away.

The capability to monitor and evaluate channel changes using these new technologies has been exploited effectively by a number of research groups, resulting in marked progress in qualitative and quantitative models linking morphological changes and adjustments of the channel to the wider-scale evolution of the surrounding catchment, floodplain, fan and valley systems.

Long-term monitoring of channel changes at study sites on unstable systems that were established in the 1970s is now yielding the hard data necessary to refine the qualitative channel evolution models (CEMs) for disturbed fluvial systems that were developed in the 1980s. While the sequences and trends of channel adjustment that comprise existing CEMs are unlikely to require major revision, the results of long-term investigations allow the intrinsic geomorphic thresholds that are crucial to CEMs to be quantified in a way previously impossible, while the increased period of record that now exists indicates that late-stage adjustments may involve meander planform evolution that was not featured in the original models.

2.4 Long-term Channel Evolution

While process-studies and field monitoring are crucial to quantifying and understanding contemporary process-form inter-relationships, it remains true that in explaining current landforms and their longterm evolution, «the past is the key to the present». Fluvial geomorphologists have continued during the last five years to perform studies aimed at unlocking the stratigraphic and sedimentary record of fluvial process-form interactions responsible for

Holocene valley formation, floodplain sedimentation and fan deposition. This work has benefited from the availability of improved methods of dating sediments, and geomorphologists have made particularly good use of the thermal luminescence technique in this regard. A related achievement is the development of sophisticated methods of palaeoflood reconstruction that draw on a wide range of evidence to produce more reliable estimates of the magnitude and duration of major landforming events.

Our improved understanding of the geomorphology of valley, floodplain and fan formation has enabled fluvial geomorphologists to relate system features and evolution to local and regional tectonics to a greater degree than ever before. Both geomorphologists and geologists now recognise the subtle interplay that can exist between fluvial forms and neo-tectonics, to the benefit of both disciplines. For geomorphologists, the opportunity exists to explain changes in, for example, channel planform on the basis of local warping of the valley floor, while geologists are better able to interpret the evidence of neo-tectonic activity presented by surficial features such as rivers.

2.5 Bio-Geomorphology

Like many geomorphologists, I was until recently guilty of under-appreciating the role of vegetation in affecting fluvial forms and processes. There was a tendency to view vegetation as a feature of the landscape which appeared only where the geomorphology allowed and which post-dated most of the significant landforming activity. Recent research has shown this simply not to be the case.

In fact, riparian vegetation is as much an integral component of the boundary conditions affecting a channel as, for example, the bank material grain size or the valley slope. Certainly, riparian vegetation can be altered by fluvial processes - but then so can the bank material composition or, given sufficient time, the valley slope! Similarly, while the input of mixed-size sediment from bank erosion can have important implications for the stability of channels downstream in the fluvial system, exactly the same can be said of the input of large woody debris (LWD) generated by retreat of a tree-covered bank.

Recent research in fluvial geomorphology and related disciplines has established clearly that the nature of riparian vegetation assemblages can influence both the evolution of unstable systems and the regime geometries ultimately achieved by stable channels. On this basis, there is no longer any excuse to delay the incorporation of vegetation effects into conceptual and numerical models of fluvial processes and channel evolution.

Recognition of the intimate relationship between channel morphology, morphological adjustments and vegetation opens up a new realm of research in which vegetation is used to monitor and interpret morphological features and changes. Considerable progress in this area was made during the 1980s, particularly through the application of dendrochronology to dating berm and proto-floodplain surfaces in unstable channels. However, in the last five years dendrochronology has been augmented by a range of new techniques in biogeography, allowing clearer and more detailed records of channel change to be constructed from the spatial and temporal distributions of riparian vegetation.

2. 6 Applied Fluvial Geomorphology

It is my personal belief that we are in something of a «golden age» of applied fluvial geomorphology. Certainly, the level of interest in geomorphology currently shown by river managers and engineers exceeds anything I have experienced in the last 25 years and there is a general acceptance that the geomorphological approach provides a useful vehicle for environmentally-sensitive and sustainable river engineering and management.

It is vital to the future strength of our discipline that we accept this opportunity to establish fluvial geomorphology as an essential component of modern environmental management. However, based on progress during the last five years, we have gone only part of the way to achieving this goal.

The period has featured an understandable, but not entirely healthy, focus on stream classification and typology. Stream classification is, of course, not new and excellent schemes may be traced back to the 1960s and 1970s. What is new, is their marketing to engineers and river managers as providing the key to understanding crucial elements of river morphology such as process-form inter-action, stability status and the likely process-response of the system to proposed engineering interventions. While stream classification is no doubt a good way to begin a geomorphological investigation it will seldom, if ever, alone provide a sufficient basis for river engineering or management. Usually, additional information will be required including, for example, at least a qualitative understanding of the sediment dynamics in the fluvial system as a whole, and a thorough understanding of the geomorphological processes operating in the reach of interest. In practice, the former may be attained through a «fluvial audit» of the system, while the latter demands a detailed «geomorphological dynamics assessment» that requires a much more intensive reconnaissance and investigation of the study reach than that performed during a channel classification exercise.

While being careful not to erode the confidence of end-users of stream classification, it is time to build on the platform established through that relatively user-friendly technique by introducing engineers and managers to new and more powerful techniques in applied geomorphology, such as the catchment baseline survey, fluvial audit and geomorphological dynamics assessment.

Perhaps the strongest growth in applied fluvial geomorphology has occurred as part of the current fashion for «river restoration». There is in developed nations a strong and welcome movement to recover as much as possible of biohabitat, recreational value and visual amenity that has been lost due to environmentally-unsympathetic engineering of rivers for flood control and land drainage. Early restoration schemes were designed by ecologists and landscape architects with little or no background in fluvial geomorphology, and many of the channels constructed require either structural works or regular maintenance in order to retain the environmental features built into them. In this respect they constitute another «technical fix» - albeit one with environmental rather than flood defence aims.

The application of fluvial geomorphology to restoration design has resulted in new and innovative approaches in two crucial areas. Firstly, fluvial geomorphology is able to provide the «catchment context» for the design of restored channels with morphological diversity and environmental stream functions that are appropriate for the current catchment flow regime and sediment dynamics and which, therefore, are more sustainable. Secondly, the insight and understanding provided by a thorough geomorphological evaluation of the project stream encourages the use of «prompted recovery» of natural morphology rather than engineering construction as a means to restoring habitat diversity. Channels and morphological features formed by the action of fluvial processes of bed scour, bank erosion and sediment deposition are, by definition, more natural than those created artificially by in-stream structures. On this basis, they should be better adjusted to the catchment context, require less maintenance and be more sustainable too.

River restoration is today still more of an art than a science, but the recent rate of progress in developing geomorphologically-led design approaches is remarkable. Restoration is one fashion that looks certain to endure and, provided that fluvial geomorphologists can deliver sound design methods, there may be a promising future for many of the world's environmentally-degraded watercourses.

2. 7 Theoretical Issues

A number of key concepts under-pinning the study of fluvial geomorphology have recently been revisited, revised and relaunched. This has involved the use of new methodologies, analytical techniques and philosophical frameworks, many of them developed in the natural sciences and mathematics, that were unavailable to earlier generations of researchers. Of course, this is nothing new as geographers have been borrowing ideas from other disciplines for decades!

There are exciting developments in the characterisation of drainage networks as non-linear, complex systems. While the application of systems theory to fluvial geomorphology already has a long and distinguished history, the adrenalin shot provided by the involvement of several young and aspiring geomorphologists, coupled with the availability of more powerful computational methods to handle the difficult mathematics, promises to advance our understanding of both system operation and response to external perturbation at reach and catchment scales.

Another long-established element of the fabric of geomorphological study that has received renewed scrutiny after a period of hiatus is the equilibrium concept. The basis for equilibrium and dis-equilibrium views of landforms and landscapes has been re-examined and the debate advanced through discussion at notable conferences and papers in esteemed journals.

Approaches to the analysis and explanation of channel morphology and morphological change based on extremal hypotheses are more recent, but no less controversial than systems theory and equilibrium concepts. These approaches involve the assumption that channel morphology adjusts to minimise or maximise a particular geomorphic parameter, examples being that slope is adjusted to minimise the time-rate of energy expenditure or that width is adjusted to maximise sediment transport capacity. While no breakthrough has been achieved in the last five years, the arguments surrounding the theory and applicability of extremal hypotheses continue to fuel vigorous discussion between the originators of various hypotheses, their acolytes and *the doubters*, who still represent the majority opinion.

3. KEY JOURNALS FOR FLUVIAL GEOMORPHOLOGY

The study of fluvial geomorphology has, like most academic activities, been affected by the current emphasis on accountability in the disbursement of public funds. The increased emphasis that the present funding regime places on research quality and outcomes makes it essential that results be published in «front line» journals that are «internationally esteemed». However, there is no common acceptance of which *are* the front line journals in fluvial geomorphology and the picture is complicated because work that contributes to our understanding of the subject may spring from one of a number of academic disciplines ranging from Civil Engineering, through Geography and the Earth Sciences, to Hydroscience.

To help elucidate which journals are most read and respected, a «straw poll» was conducted amongst a selection of internationally recognised by active researchers in fluvial geomorphology. These results are unscientific and should not be treated too seriously, but they do, perhaps, indicate the locations where active researchers most often anticipate finding useful and groundbreaking material.

In the field of geomorphology, two journals dominated the responses. While, *Earth Surface Processes and Landforms*, remains unquestionable the most highly esteemed journal, the gap between it and *Geomorphology* is closing.

Water Resources Research, was also mentioned by all respondents. There is within the American Geophysical Union a relatively small but very active group of fluvial geomorphologists who continually promote sessions devoted to geomorphology at the Spring and Fall AGU Meetings and who contribute to maintaining the flow of good geomorphological papers to WRR. They are to be commended for these efforts.

Beyond these three journals, there are clearly a wide variety of outlets for current research findings in fluvial geomorphology. Journals mentioned by one or more of the respondents included (in alphabetical order):

- Hydrological Processes
- Journal of Fluid Mechanics
- Journal of Hydraulic Engineering

- Journal of Hydrology
- Nature
- Regulated Rivers
- Science
- Sedimentology

4. RESEARCH ISSUES

Notwithstanding the excellent progress made since the last International Geomorphology Conference, there are a number of burning issues that face fluvial geomorphology at the end of the 1990s. The theme that I have chosen for a brief review of these issues is that of *linkages.*

4.1 Links - The key to the future of Fluvial Geomorphology

The future of fundamental and applied fluvial geomorphological research lies in developing and applying our capability to recognise, explore and establish links in a series of key areas including:

1) the links that bind different reaches and rivers in the fluvial system;
2) the links that unite researchers using different approaches but working towards a common goal of progress in fluvial geomorphology;
3) the physical links that connect channels to their surroundings in the basin and landscape, and the cultural links to communities of floodplain dwellers;
4) the links that bridge the disciplinary divides between fluvial geomorphology and related branches of Earth Science, Engineering, Environmental Science and Social Science.

4.2 Links within the Fluvial System

Links within the fluvial system can be considered in two dimensions: scale and time. Scale links must better relate current fluvial processes at grain or bedform-scale to the morphology not only of the surrounding channel, but also that of floodplain, valley, or fan within which the channel is located. It is important that process studies recognise that local conditions are inexorably linked to the dynamics of the fluvial system and that studies of local process-form inter-actions should no longer be undertaken without regard for the wider, catchment context.

Historical links must also be strengthened, even in studies ostensibly concerned with contemporary flow mechanics and instantaneous rates of sediment transport. The reason for this is simple: almost everything that we have learned in the last five years reinforces the idea that antecedent conditions are important in conditioning current processes and morphological responses. With a very few exceptions, knowledge of the sequence of catchment changes, formative flow events and channel evolution in the preceding months, years, decades and even centuries will assist the researcher enormously in understanding and explaining the present situation.

43 Links in Research Methods and Approaches

Modern research in fluvial geomorphology takes place in a variety of places and involves a wide range of approaches. While the catholic nature of geomorphological research is one of its great strengths, contrasts in the philo sophical stances, numerical sophistication and technical hardware employed by different research groups can be divisive.

Our science will better advance if links are maintained and strengthened between groups working in different places, such as the field, laboratory and cyber-space. The research outcomes will benefit if theoreticians have links and inter-act frequently with empiricists. Progress will be enhanced if we can better link modellers to reliable data sets. Finally, the development of geomorphology as a profession rests on encouraging stronger links and mutual respect between academics and practitioners.

4.4 Inter-Disciplinary Links

The study of rivers is fundamental to many branches of natural science, engineering and social science. The common interests that fluvial geomorphologists share with earth scientists, engineers, environmental scientists, ecologists, human geographers and social scientists ought to promote strong and mutually beneficial links between these disciplines. In practice, individuals working on the same river, but with different beliefs and backgrounds, too often allow the fact that they are not «like-minded» to prevent them from cooperating with one another. This inhibits the exchange of ideas and information that is so often the key to making a research breakthrough.

4.5 Practical and Enabling Links

The opportunity for fluvial geomorphologists to communicate is now greater than ever. The internet can be used to gather and disseminate information in a way simply impossible just a decade ago. It is incumbent upon us to make use of this unique opportunity, to the advantage of the global community of fluvial geomorphologists.

Anybody with access to a web site could start today and I urge every reader of this article to do just that. Contact the web master at your home institution and discuss with him or her how to make the outputs of your research labours available to interested parties around the world. Typically, you might wish to share your publications list, unpublished research reports, geomorphic maps, computer models (including user manuals), or data sets (including explanatory text).

I am not suggesting that any confidences be breached or that intellectual property rights be infringed, but there are masses of articles, models and data sets that could, in theory, be put in the public domain, but which are, in practice, unknown or inaccessible to the vast majority of potential end-users.

I would like to suggest a new strategy for research (and career) advancement:

Be known by your model and your data as well as your publications!

4.6 Links in Applied Fluvial Geomorphology

The fact of the matter is that at the end of the second millennium we can no longer afford to have specialists from different disciplines working in isolation, or even in interdisciplinary projects - the need now is for truly multidisciplinary teams equipped to address complex environmental issues holistically, and capable finding sustainable solutions to immensely difficult environmental problems.

Such is the gravity of the situation concerning many of the world's great rivers that the time for confrontation is past. Conflicting goals must be reconciled through cooperation and optimisation. This means that strategic planners and river managers must start to take «peoples participation» and the involvement of local interest groups seriously. It also means that single-issue environmental pressure groups - many of which appear to be anti-engineering and oppose ALL river development or engineering project on principal - must take a more mature and realistic attitude that recognises the need to balance the needs of nature against the legitimate desire of floodplain dwellers in developing nations to improve their standards of living.

Fluvial geomorphologists are well placed to serve in multi-disciplinary teams and help to form links between planners, engineers and environmentalists. However, their position is weakened in this respect through lack of credibility. There is a growing body of opinion, especially amongst younger fluvial geomorphologists, that our discipline and its utility in applied research and consultancy would be greatly enhanced through the provision of a professional status that matches that of the registered or chartered professionals we work alongside.

If this is to be achieved, leadership is urgently required from our learned and professional Institutes, Associations and Societies to establish professional status for geomorphologists.

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PAOLO BILLI

SEDIMENT DYNAMICS AND RIVER MORPHOLOGY

In the morning session, entitled «Sediment dynamics and river morphology», 29 poster were presented by scientist coming from 16 different countries, namely: Australia, Belgium, Canada, India, Israel, Italy, Japan, New Zealand, Nigeria, Poland, Romania, Russia, South Africa, Spain, United Kingdom, and the United States of America.

The poster presented cover many topics describing the dynamics of sediment from slopes, where erosion prevails, to the main river channels whose morphology is largely affected by sediment transport and deposition processes.

5 posters dealt with topic related to the general theme of *Slope erosion processes and sediment yield* and range from gully head collapse modelling to studies on the erosive capability of rainsplash on surfaces with different landuse or report about field measurements of sediment yield by maens of both conventional and modern techniques such as Caesium 137.

The general theme of *Sediment transport* received the largest attention by the attendess of the Fluvial Geomorphology Session as 15 posters were presented in this section. These posters focus on many aspects of this very important but still not completely understood process. Field investigations and measurements, laboratory flume studies and theoretical approaches are presented. Field studies have been carried out on rivers with very different geomorphic and hydrologic characteristics embracing a very wide set of situations, from ephemeral streams of arid environments to river systems of more humid areas. The still intriguing problem of downstream decline of bed material grain size is addresed by a couple of prosentations, while the interaction between sediment size and both channel and alluvial plain morphology is faced by other 5.

Flow and sediment transport models are presented by two posters. Sediment transport paths, determined in an estuary with granulometric and bedform orientation methods and suspended sediment yield measurements in a river deeply affected by natural and anthropogenic erosion processes are also illustrated.

9 posters investigate the relations between *River hydraulics and channel morphology*. Studies on the physical processes influencing bank and channel stability, with particular emphasis on the role played by vegetation are illustrated in 4 posters. The influence of pebble clusters on the turbolent flow structure in a gravel-bed river and the effects of the interaction between the flow and meso and macro bedforms on channel morphology has bean investigated by field measurements and theoretical approach respectively. Finally, statistical analysis of bed elevations to quantify changes in bed roughness and bed pattern in time and studies on flood variation following channellization are presented. The significance of channel location changes with respect to observed trends of flood magnitude is also pointed out.

The general theme of the evening session was *River response to natural changes and human impact*. A slightly larger number of poster (32) than the moming section was presented and an even wider international ambit as 18 countries are represented: They are: Albania, Belgium, China, Germany, India, Italy, Japan, Korea, Morocco, Poland, Rumania, Russia, Slovenia, Spain, Taiwan, Ukraine, United Kingdom and the United States of America.

6 posters report about case studies on *River response and adjustment to haman impact* in different part of the world. Examples of human intervention at both channel and catchment scale (namely land use changes) and the relative channel changes at different time scales are reported. The analysis of historical maps and documents is the main source of information in a couple of presentation, while other investigate the effects of the construction of dikes and dams on an ephemeral stream or point out the relevance of channel form and processes identification and of channel stage evolution identification in river engineering management and restoration.

Only 1 poster deals with the *River hydrology* section. It illustrates a study on the cause of landform difference in serpentinite area. It also reports an investigation on spatial variations of baseflow discharge among different lithologies and measurements of runoff response from small basins in serpentinite and other lithologies.

The mode and the causes for the development of *Drainage patterns* are analysed in 9 posters. Conceptual modelling of river system evolution implying hierarchical and a functional structures is presented, while the significance of cause/effect relations between morphogenetic processes and plano-altimetric configuration is examined through the analysis of many basins with different tectonic history and geomorphological characteristics. Geomorphic analysis studies are presented by other two posters. The first deals with the use of a new topographic parameter based on contour lines langth which permits to differentiate three classes of basins and particularly badiands; the second regards the definition of regional differences in bedrock and alluvial channel morphology by means of the area-slope thresholds and influence of sediment supply. 3 posters investigate the geologic control on river morphology. The present morphology and evolution of Transylvanian depression rivers are described as reflecting different tectonic structures in the area, while the longitudinal profiles of rivers in a stable setting in Ohio and the development of gorges are studied in order to asses meltwater discharge. Finally, hillslope evolution is modelled by incorporating rates of creep, wash and landslides and by relating the form and steepness of abandoned slopes to the height of tho bedrook meander floor above the modern stream.

3 poetere are concerned with the work of geomorphological mapping of *Alluvial Plains*. The first is a new geomorphological map of the Po plain with a datailed classification of landforms based on morphogenetic criteria which is the outcome of co-ordinated activities by more than, 10 universities and research institutions of northern Italy. The second poster consists of a geomorphological map representing the evolution processes and forms that influenced the formation of the Coghinas River Valley during the Quaternary. The third one report about the investigation on two buried palaeochannels (Po river tributaries) by means of electrical sounding and drillings.

Statistical analysis is also used to built a geomorphological map of the study sites.

The 4 posters of the next section address a presently very popular topic, that is: *Climate change and river dynamics*. These presentations report about erosion and alluvial history induced by climatic changes and glacioisostatic movements in central Russia; essential geomorphological feature of river valleys in north~eastern Albania; an investigation on small alpine basins sedimentation stratigraphy and chronology to point out the relationship between climatic changes which are reflected in timberline fluctuations and climatic changes affecting the sediment supply rate; and qualitative and quantitative study on the response of fluvial systems to climatic changes of a Japanese river whose terrace sediments are interpreted from the viewpoint of palaeohydraulics.

The last poster of the previous section introduces us to the topic of *Alluvial terraces* which is covered by 7 presentations. These studies report about the evolution of the downstraeam reach of the Moulouya river in Morocco and the influence of regression and transgression cycles on fluvial terraces development and characteristics; the influence of landmass uplifiting on terraces formation in different areas of Taiwan; the Description of the sedimentology of different climatic terraces deposits in northern Ukraine; the application of remote sensing in investigation on fluvial processes and resulted landforms (namely terraces) in west Bengal (India); river systern evolution due tectonic movements, glaciations, alternation of aggradation and degradation in the western Okhotsk area in Russia and the use of luminescence in dating river terraces in China.

The last topic regards *Alluvial fans and deltas* and it is treated only by 2 posters. The first deals with alluvial fan doposits interpretation and reconstruction of flood wave characteristics from sediment layers sequences and sedimentary structures, while the second reports about the analysis of fan distribution according to relief in Japan, Taiwan and Philippines. Investigations of the effects of drainage basin area, intermontane basin area, relief ratio climatic conditions and sedimentary environments on fan development are carried out and the influence of climate with alternation of dry and wet seasons on fan formation is examined.