Inhibition of Autogenic Dynamics in Alluvial Fans: Field Examples from the Tertiary of Spain and Implications for Process Recognition in Fan Successions*

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Search and Discovery Article #50333 (2010)
Posted October 18, 2010

* Adapted from an oral presentation at AAPG Annual Convention and Exhibition, New Orleans, Louisiana, USA, April 11-14, 2010

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Abstract

Alluvial fans are depositional systems with a relatively simple organization, due to close physical coupling between a sediment source and an adjacent transfer/accumulation area.

Nonetheless, general models of fan evolution and stratigraphy are still inadequate, due to the very high sensitivity (and often case-specific responses) of such systems to allogenic controls.

Autogenic processes complicate this picture, being an intrinsic component of alluvial fan development. A distinction is here made between “lateral autogenic dynamics”, tied to local topographic constraints on sediment distribution, and “vertical autogenic dynamics”, related to base-level /sediment-transport feedbacks in the building-up and out of clastic wedges.

The role of autogenic factors has been only recently highlighted by numerical and physical modelling, but remains unexplored in field-based studies, because of inherent difficulties in detecting ultimate causal relationships in the architecture of coarse-clastic successions at basin margins.

An example is presented here from the margin of the Tertiary Teruel Basin (central Spain), in which excellent outcrops consent to examine the stratigraphic architecture of a Miocene alluvial fan that evolved during a protracted phase of endorheic drainage and high sediment supply. This combination of factors promoted a regime of forced aggradation in the whole clastic dispersal system, coupled

with particularly high sedimentation rates for a continental setting, as demonstrated by sedimentological and stratigraphic evidence in mudflat to ephemeral lacustrine deposits of distal settings.

Fan outcrops are characterized by a perfectly conformable architecture of stacked clastic sheets with variable character through time, due to interacting catchment, tectonic, and climatic controls, but with no evidence of internal unconformities, preserved feeder channels or fan segmentation. This points to an essentially continuous regime of aggradation, with recognizable “lateral autogenic” processes, but complete inhibition of “vertical autogenic” dynamics.

Alluvial fans are important gateways for sediment distribution basinwards. Geological factors that dampen large-scale autogenic processes in fan construction, and related field-criteria for their recognition in ancient deposits, are discussed also in relation to examples from the Ebro Basin and in terms of their significance for the analysis of sediment dispersal in continental settings.

Selected References

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INHIBITION OF AUTOGENIC DYNAMICS IN ALLUVIAL FANS

FIELD EXAMPLES FROM THE TERTIARY OF SPAIN AND IMPLICATIONS FOR PROCESS RECOGNITION IN FAN SUCCESSIONS

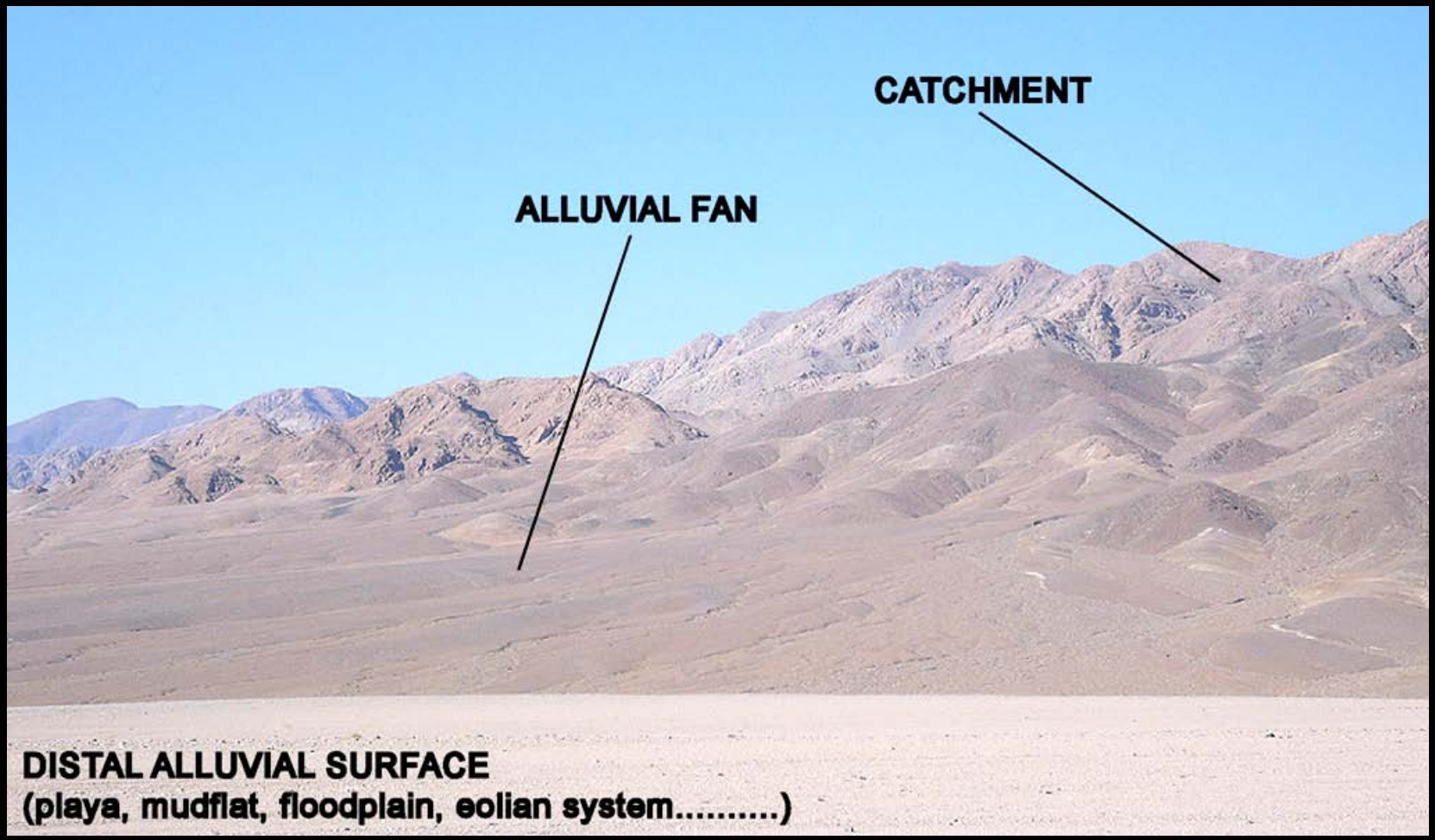
DARIO VENTRA

Faculty of Geosciences, University of Utrecht (The Netherlands)

sedimentology
Utrecht University

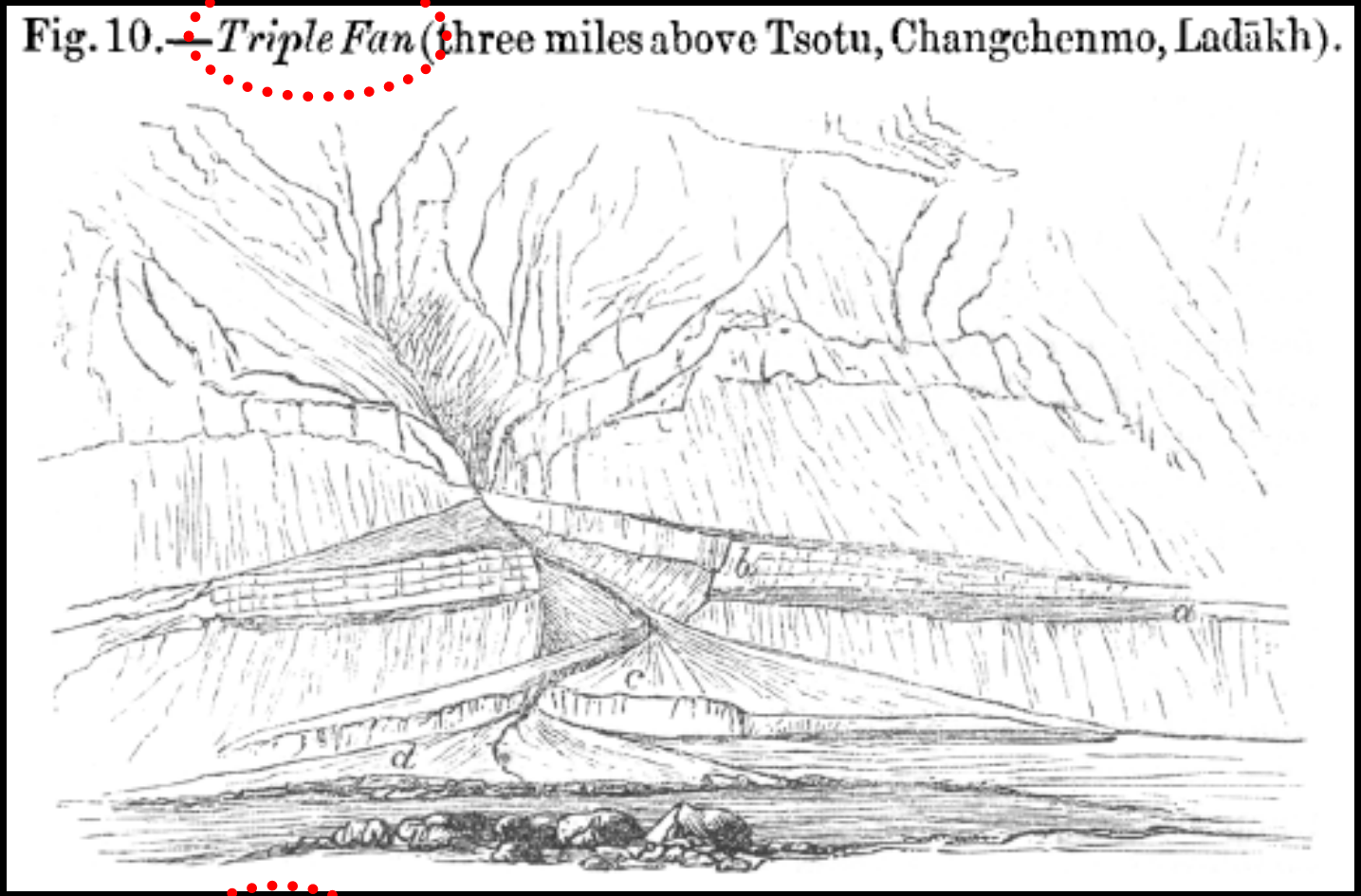
AAPG
Annual Convention & Exhibition

WE MIGHT CONSIDER ALLUVIAL FANS AS THE MOST BASIC DEPOSITIONAL SYSTEM: SOURCE AREA + DEPOSITIONAL RELIEF…



ATACAMA DESERT, NORTHERN CHILE

…BUT THIS HAS LONG BEEN RECOGNIZED NOT TO BE QUITE THE CASE!!



from Drew, 1875, *Quarterly Journal of the Geological Society*
"*ALLUVIAL AND LACUSTRINE DEPOSITS AND GLACIAL RECORDS OF THE UPPER-INDUS BASIN*"

- **ALLUVIAL FAN RESEARCH…**
- **…AND THE POSSIBLY OVERLOOKED ROLE OF AUTOGENIC PROCESSES IN FIELD STUDIES**
- **TERUEL BASIN: EXAMPLES AND RATIONALE**
- **EBRO BASIN: ANALOGUES**
- **CONCLUSIONS**

SHOULD WE BE LOOKING AT TECTONICS??

ALLUVIAL FAN SEQUENCE AND MEGASEQUENCE MODELS:
with examples from Westphalian D — Stephanian B coalfields, Northern Spain

ALAN P. HEWARD

Fan Deltas: Sedimentology and Tectonic Settings
Eds. W. Nemec and R.J. Steel

Coarsening-upward and skewed fan bodies: symptoms of strike-slip and transfer fault movement in sedimentary basins

R.J. STEEL

SHOULD WE BE LOOKING AT TECTONICS??

Journal of the Geological Society, London, Vol. **146,** 1989, pp. 507–508. Printed in Northern Ireland

Alluvial fans and their tectonic controls

C. P. NORTH, S. P. TODD & J. P. TURNER
Department of Geology, University of Bristol, Queen's Road, Bristol BS8 1RJ, UK

The American Association of Petroleum Geologists Bulletin
V. 71, No. 2 (February 1987), P. 135-155, 14 Figs., 1 Table

Laramide Thrust-Generated Alluvial-Fan Sedimentation, Sphinx Conglomerate, Southwestern Montana[1]

P. G. DECELLES,[2] R. B. TOLSON,[3] S. A. GRAHAM,[3] G. A. SMITH,[4]
R. V. INGERSOLL,[5] J. WHITE,[6] C. J. SCHMIDT,[7] R. RICE,[8] I. MOXON,[3] L. LEMKE,[9]
J. W. HANDSCHY,[10] M. F. FOLLO,[11]
D. P. EDWARDS,[12] W. CAVAZZA,[5] M. CALDWELL,[7] and E. BARGAR[13]

OR SHOULD WE EMPHASISE CLIMATE……?

Geomorphology, 8 (1993) 287–304
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Quaternary evolution of Cedar Creek Alluvial Fan, Montana

J.B. Ritter[1], J.R. Miller, Y. Enzel, S.D. Howes, G. Nadon, M.D. Grubb, K.A. Hoover, T. Olsen, S.L. Reneau, D. Sack, C.L. Summa, I. Taylor, K.C.N. Touysinhthiphonexay, E.G. Yodis, N.P. Schneider, D.F. Ritter and S.G. Wells

1986 Indiana University Research Seminar, Indiana University Geologic Field Station, Cardwell, MT 59721, USA

Chapter 24

The Role of Climatic Change in Alluvial Fan Development

Ronald I. Dorn

Journal of the Geological Society, London, Vol. **146**, 1989, pp. 527–538, 11 figs. Printed in Northern Ireland

Climatic versus tectonic controls of fan sequences: lessons from the Dead Sea, Israel

LYNNE E. FROSTICK[1] & IAN REID[2]

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(…OR HOW ABOUT JUST GIVE UP……)

Chapter 24

8 Climatic Hypotheses of Alluvial-fan Evolution in Death Valley Are Not Testable

Ronald I. Dorn
Department of Geography, Arizona State University
[illegible]
[2]Birkbeck College, University of London, Malet St, London WC1E 7HX, UK

LECCE (1990): STILL A VALUABLE SUMMARY OF THE CURRENT STATE OF FAN AFFAIRS!

CHAPTER 1

The Alluvial Fan Problem

Scott A. Lecce
Arizona State University, Tempe

- ALLUVIAL FAN RESEARCH…
- …AND THE POSSIBLY OVERLOOKED ROLE OF AUTOGENIC PROCESSES IN FIELD STUDIES
- TERUEL BASIN: EXAMPLES AND RATIONALE
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PROBABLY THE MOST OVERLOOKED COMPLICATION IN FIELD-BASED STUDIES

AUTOGENIC FAN BEHAVIOR

ALLUVIAL FANS OF THE CUCAMONGA DISTRICT, SOUTHERN CALIFORNIA

ROLLIN ECKIS
Pomona College, Claremont, California

THE FIRST… ECKIS (1928, *Journal of Geology*)

Sedimentology (1991) **38**, 567–590

Controls on synorogenic alluvial-fan architecture, Beartooth Conglomerate (Palaeocene), Wyoming and Montana

P. G. DeCELLES, M. B. GRAY, K. D. RIDGWAY, R. B. COLE, D. A. PIVNIK*, N. PEQUERA *and* P. SRIVASTAVA

Department of Geological Sciences, University of Rochester, Rochester, NY 14627, USA

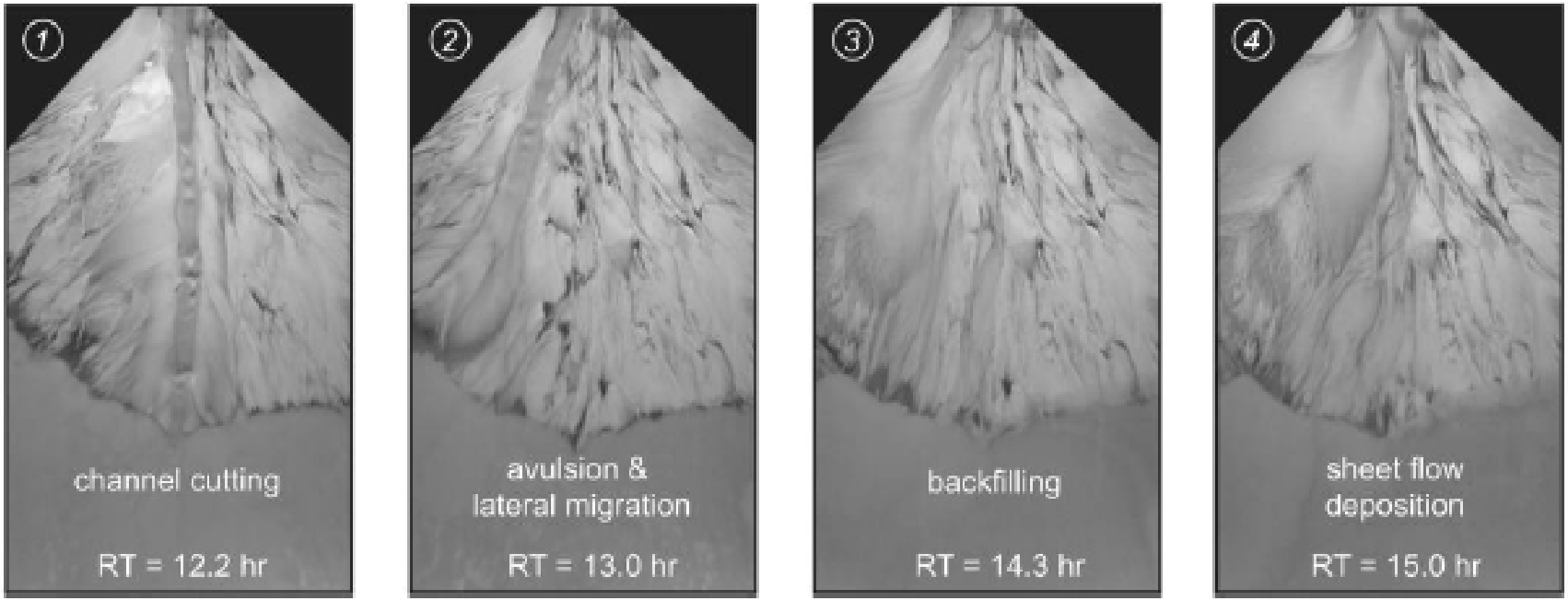
…AND THE BEST… DeCELLES et al. (1991, *Sedimentology*)

RECENT EXPERIMENTAL EVIDENCE SHOWS SUCH SIMPLE DEPOSITIONAL SYSTEMS ARE CHARACTERIZED BY INTRINSIC AUTOGENIC CYCLES OF SELF-INCISION AND AGGRADATION…

…IN ALLUVIAL FANS…

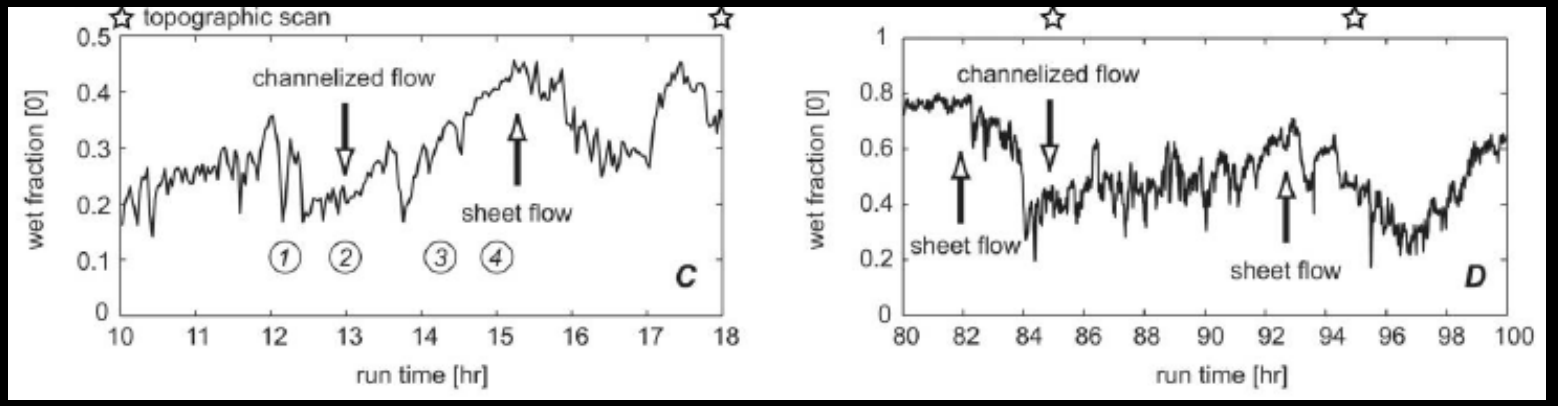
M. VAN DIJK (*EUROTANK LABS*, UTRECHT UNIVERSITY)

***SEDIMENTOLOGY*, 2009 and in press**



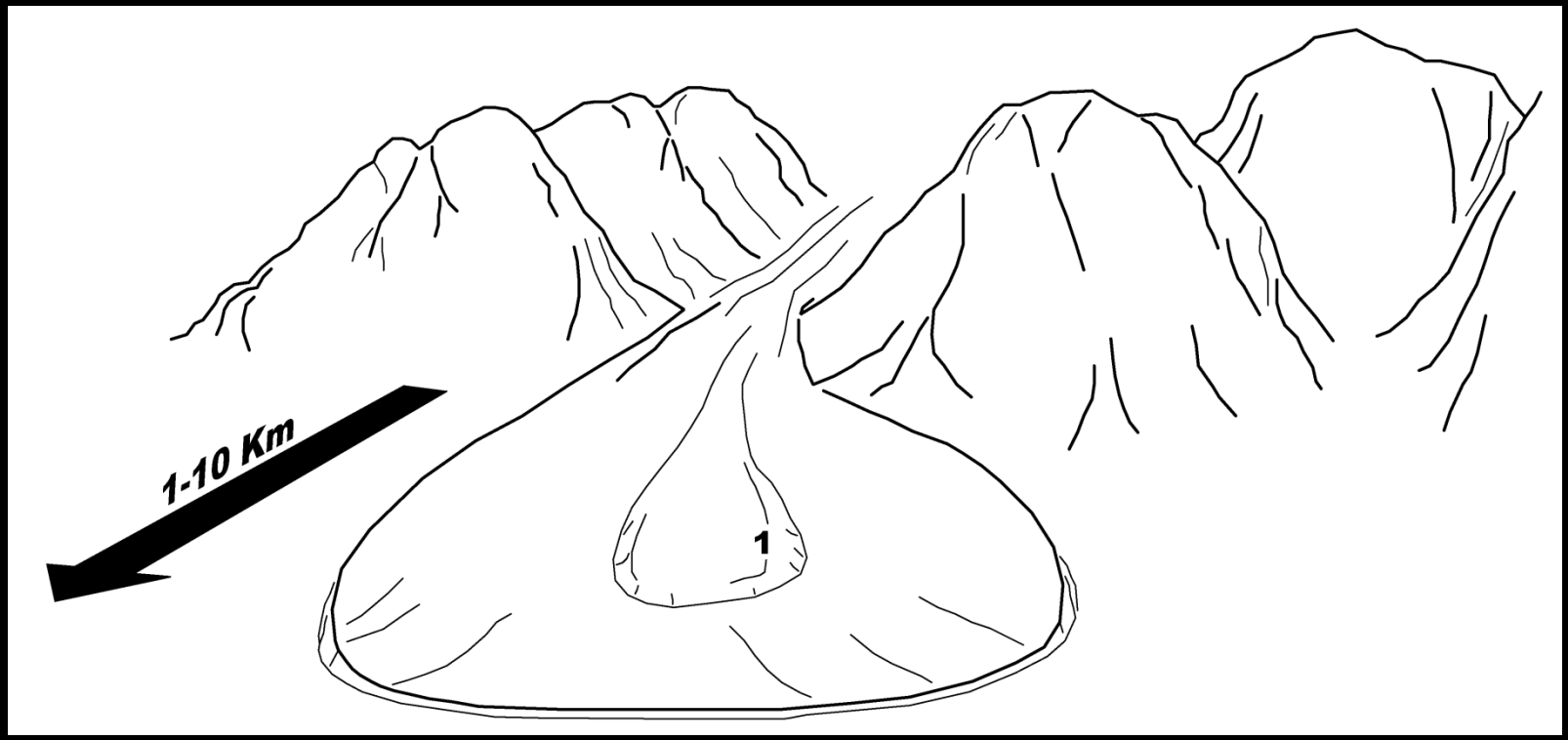
W. KIM (*EXPERIMENTAL EARTH-SCAPE LABS*, UNIVERSITY OF MINNESOTA)
***JOURNAL OF GEOLOGY*, 2008**

… AND IN FAN DELTAS



TWO BASIC TYPES OF AUTOGENIC DYNAMICS CAN BE IDENTIFIED IN ALLUVIAL FANS

1. “HORIZONTAL” DISTRIBUTARY- DEPOSITIONAL BEHAVIOR



TOPOGRAPHIC COMPENSATION OF MASS-FLOW AND SHEETFLOOD TRANSPORT PATHWAYS…

DISTRIBUTARY CHANNEL AVULSION…

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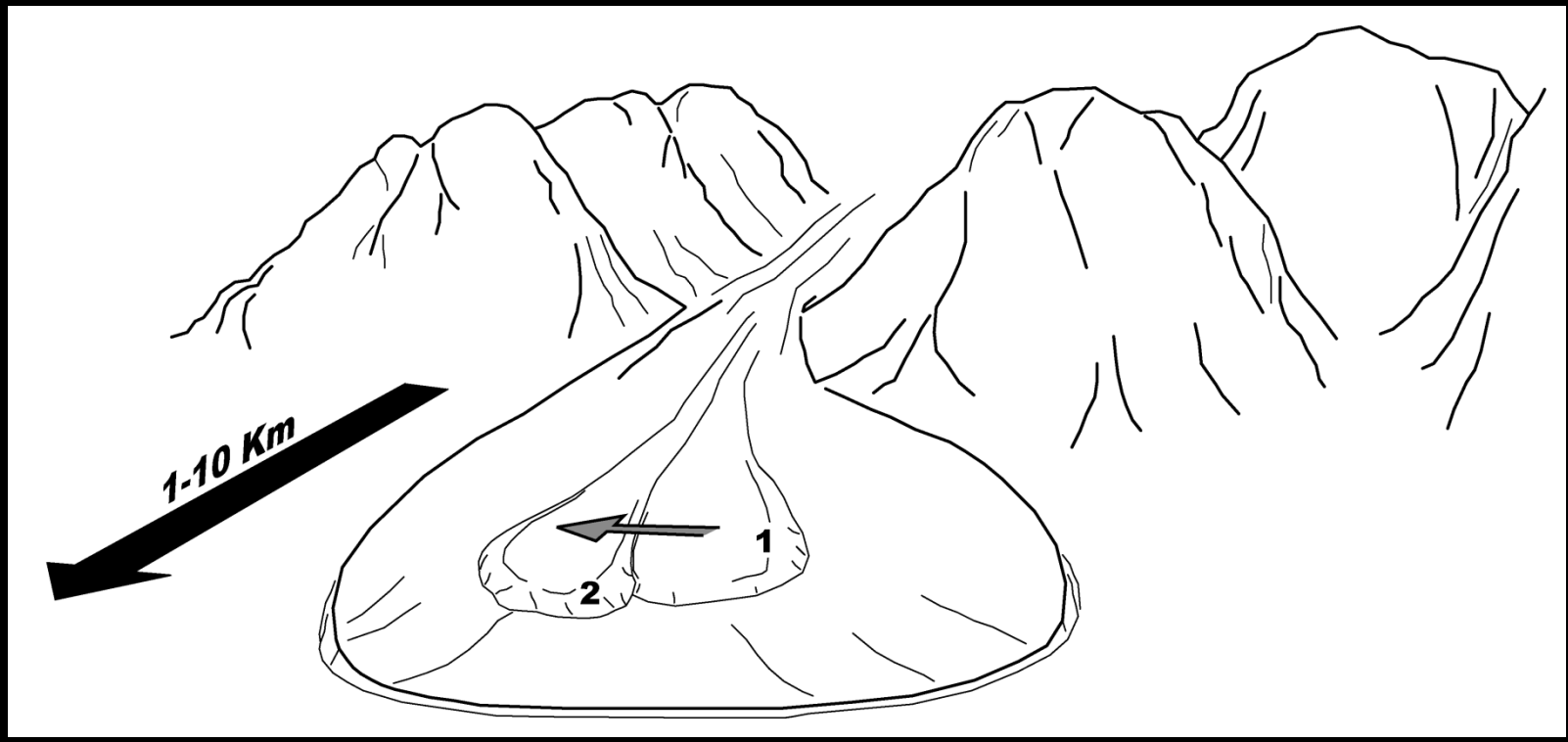

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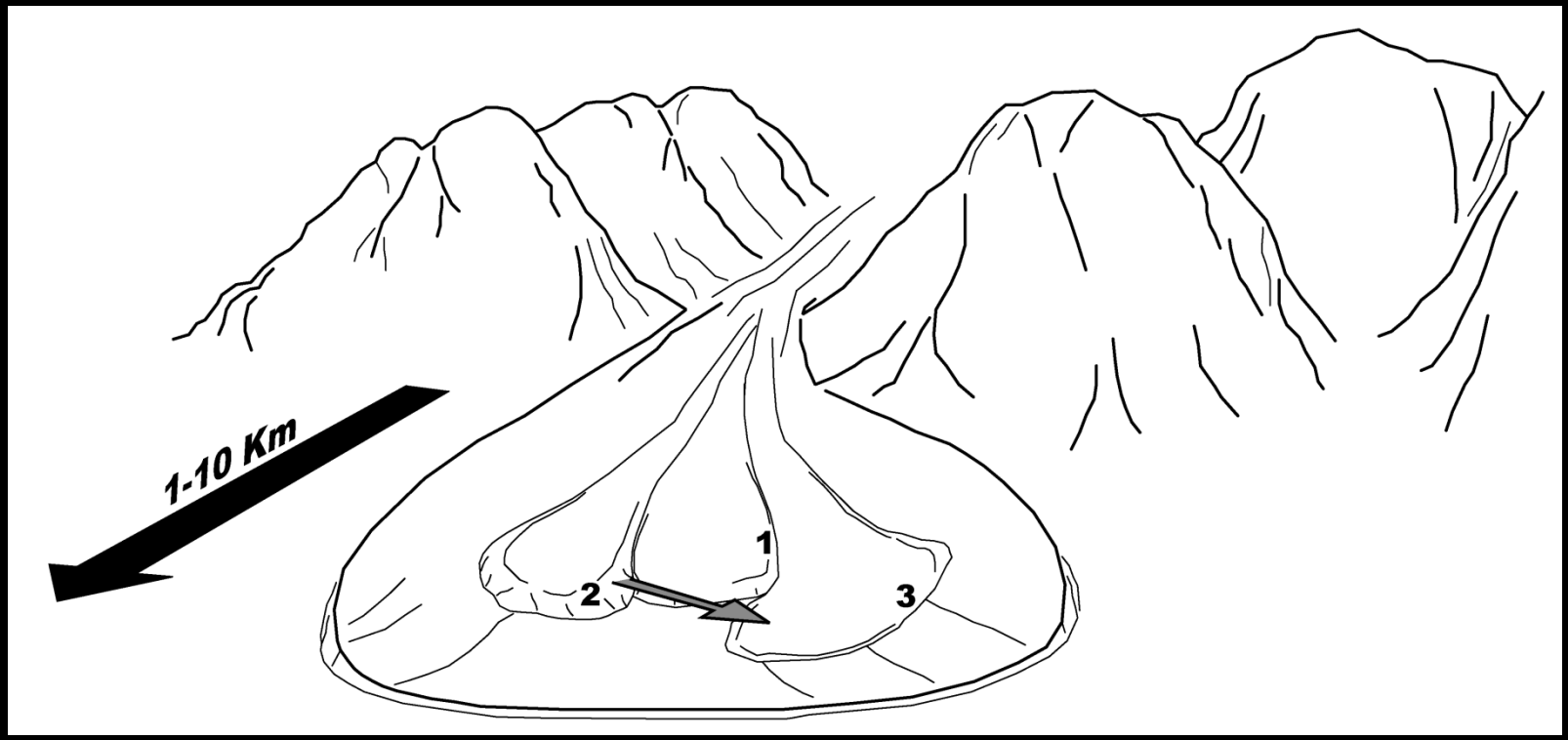

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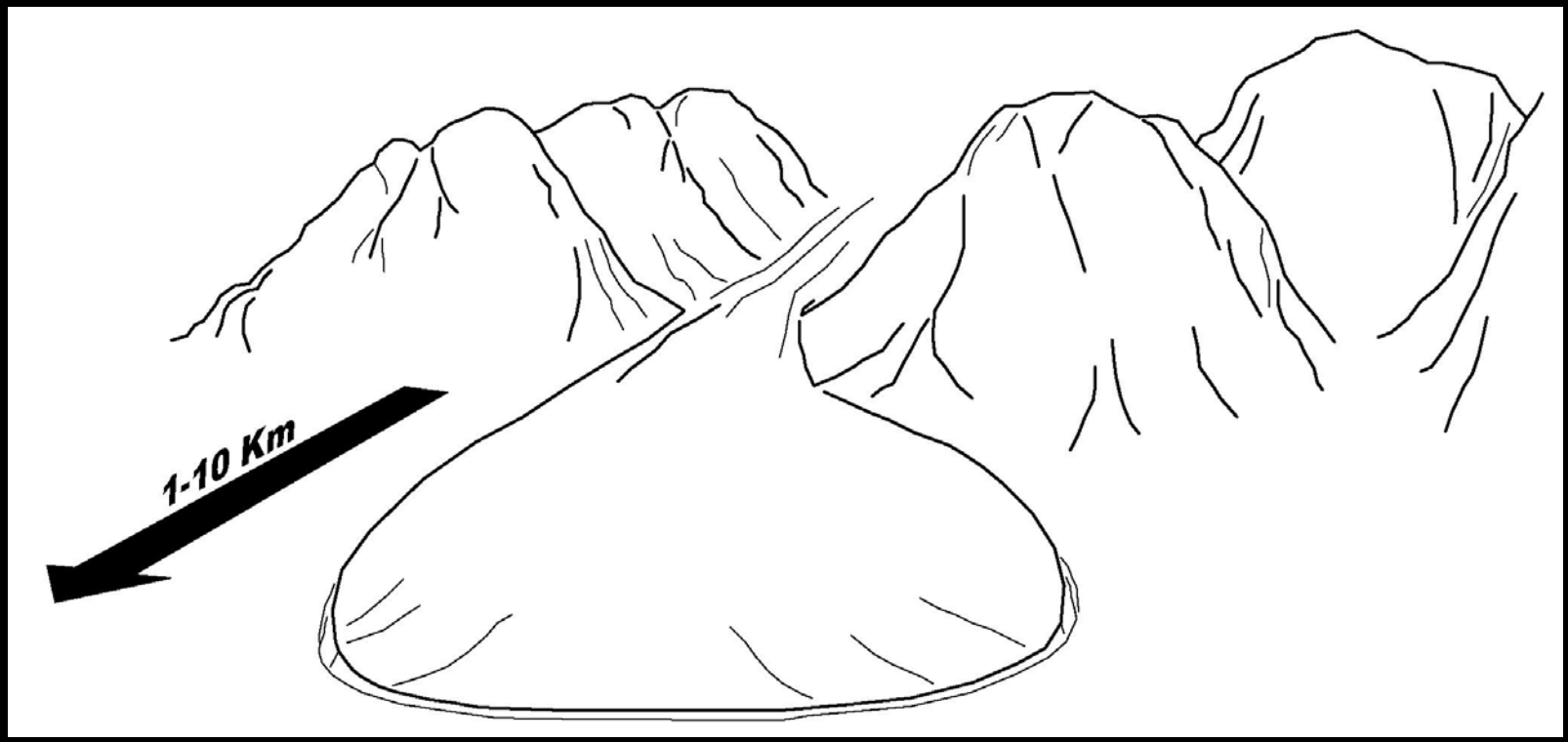
2. “VERTICAL” AGGRADATIONAL- INCISIONAL BEHAVIOR



FORMATION AND / OR EXTENSION OF AN INCISED FEEDER CHANNEL…

FEEDER-CHANNEL BACKFILLING AND PREVALENT UNCONFINED DEPOSITION OVER FAN SURFACE…

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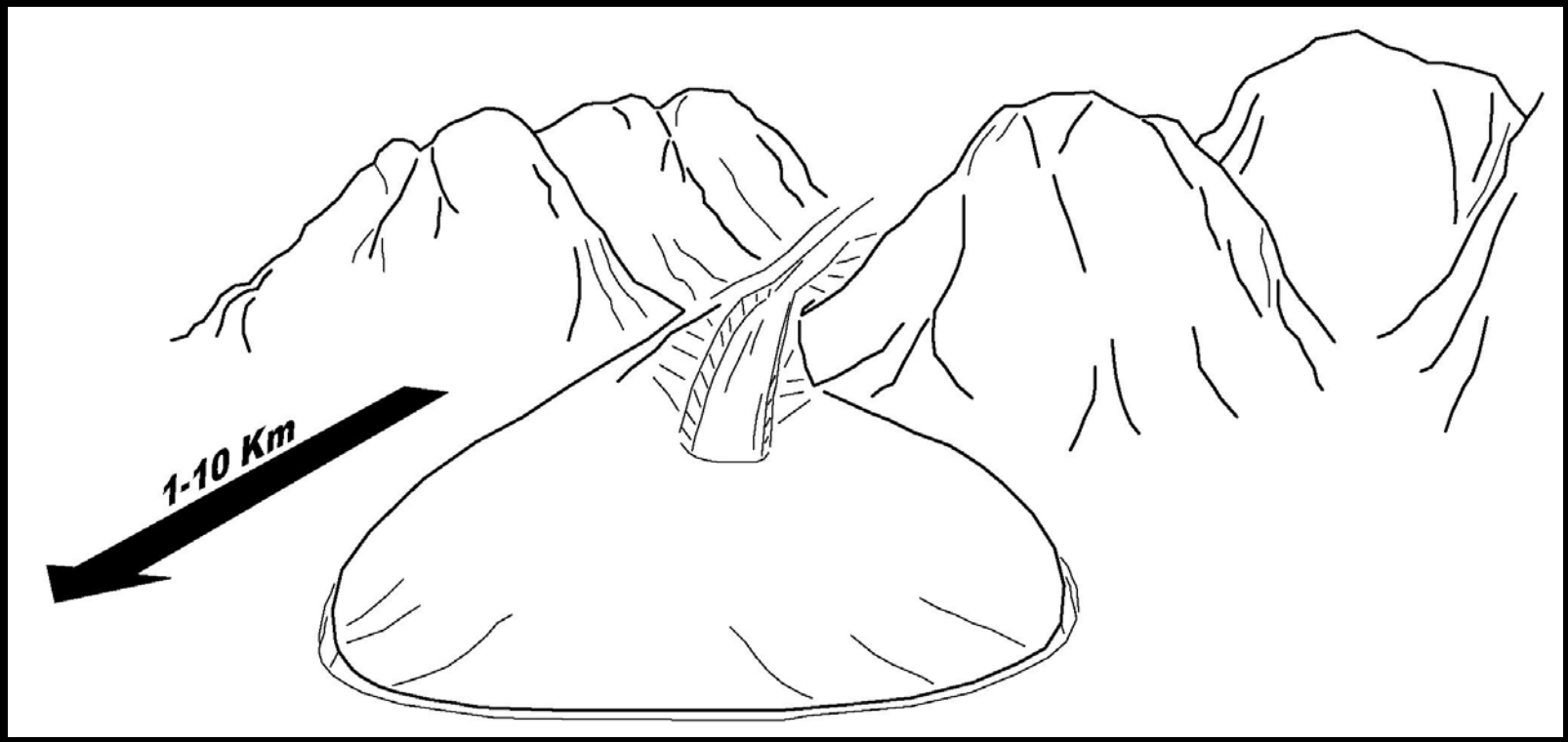

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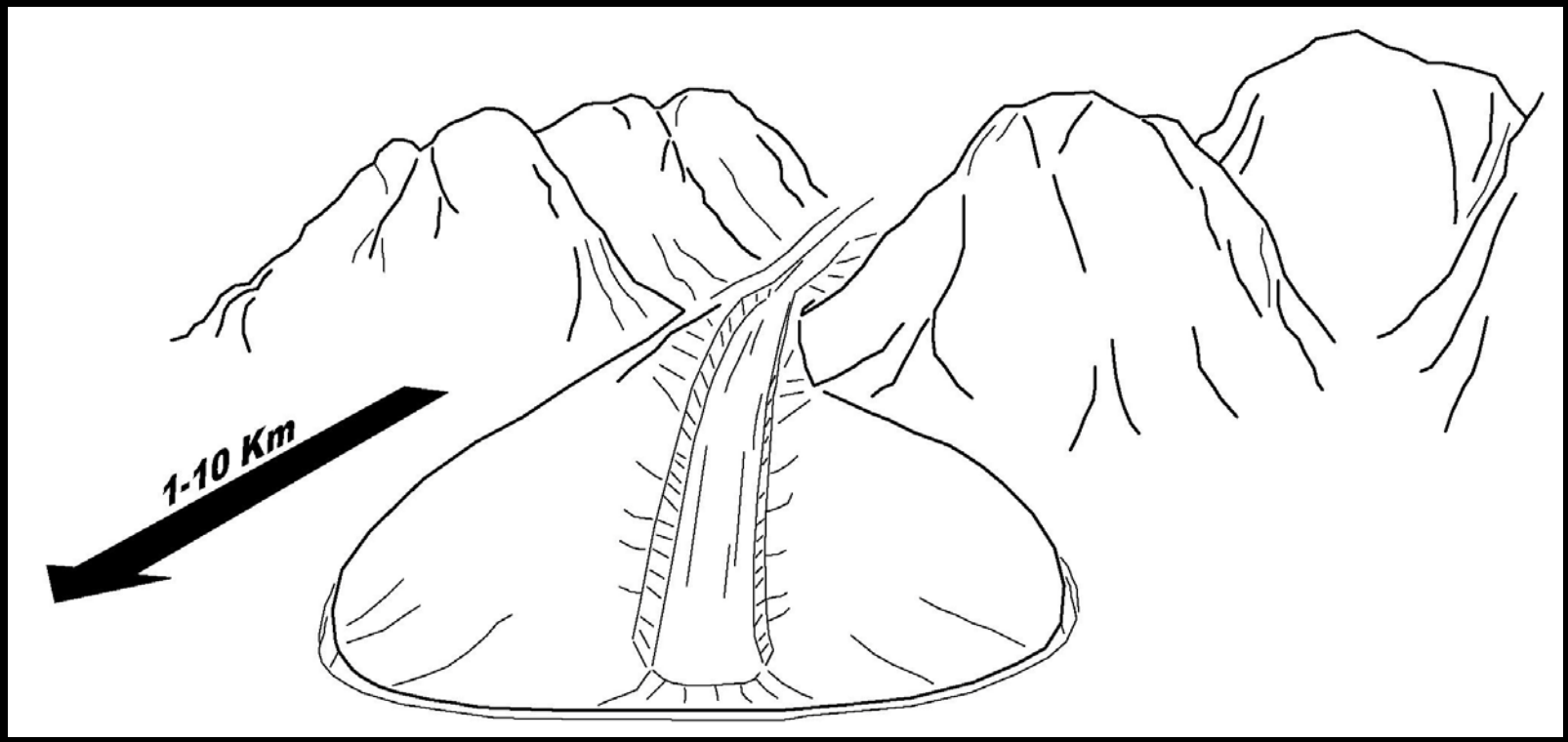


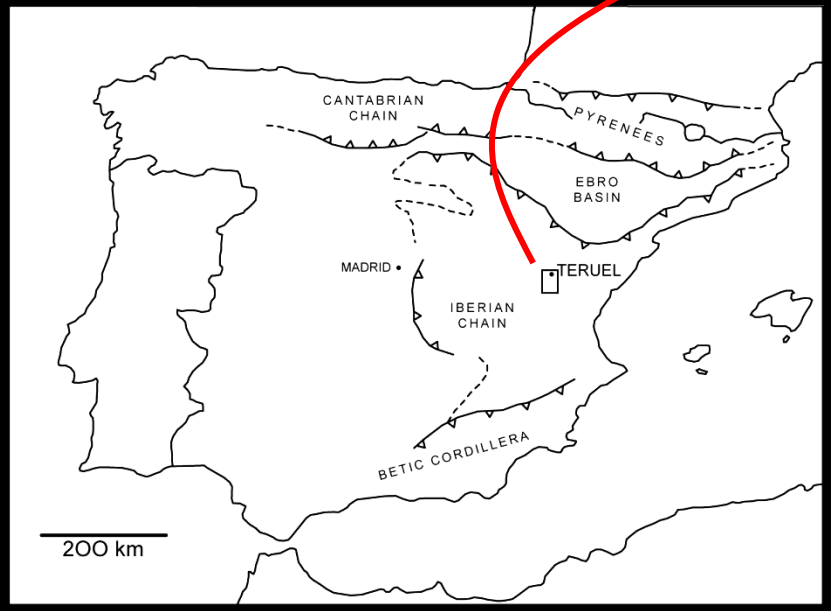
FORMATION AND / OR EXTENSION OF AN INCISED FEEDER CHANNEL…

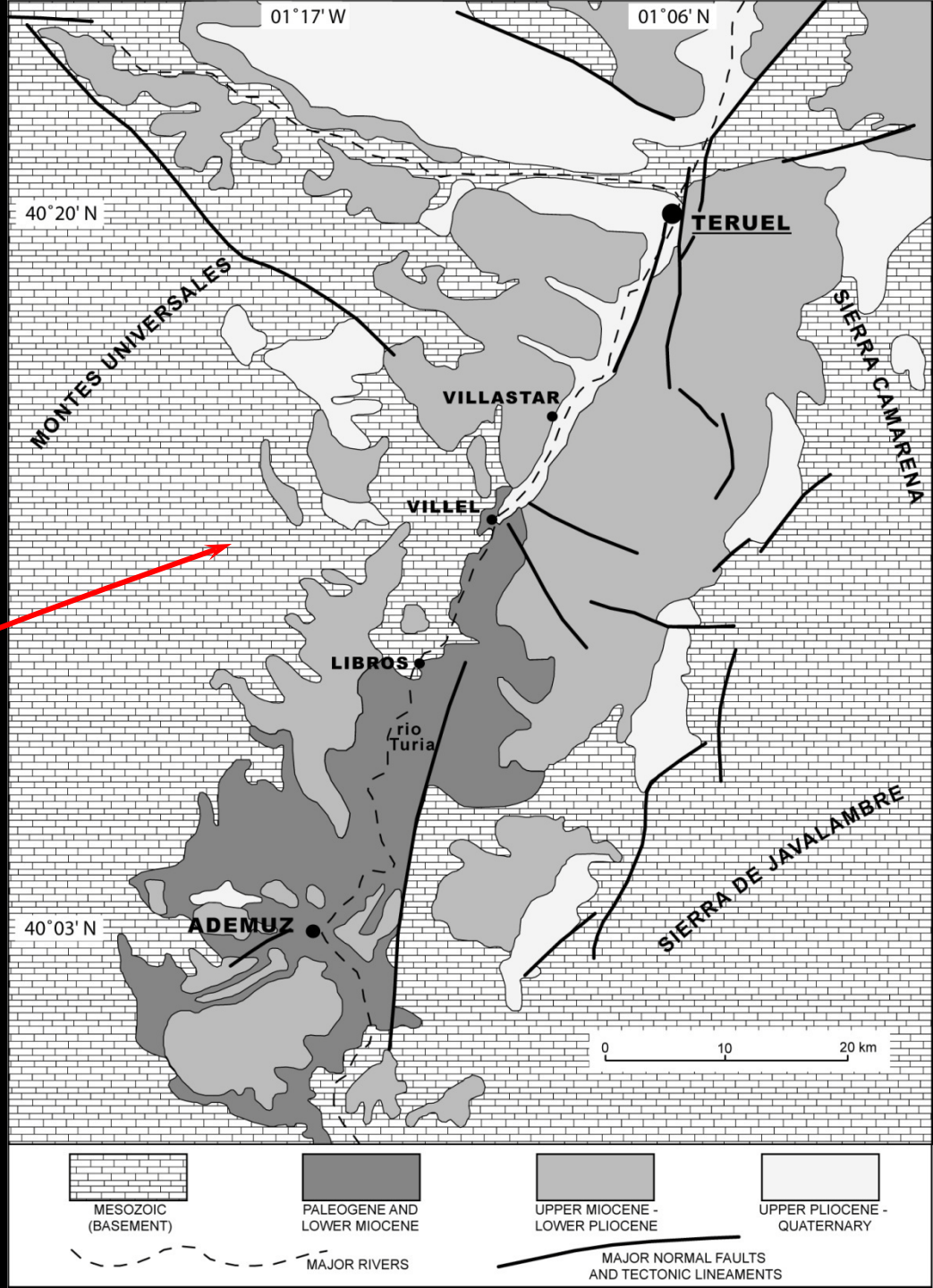
FEEDER-CHANNEL BACKFILLING AND PREVALENT UNCONFINED DEPOSITION OVER FAN SURFACE…

- ALLUVIAL FAN RESEARCH…
- …AND THE POSSIBLY OVERLOOKED ROLE OF AUTOGENIC PROCESSES IN FIELD STUDIES
- TERUEL BASIN: EXAMPLES AND RATIONALE
- EBRO BASIN: ANALOGUES
- CONCLUSIONS

TERUEL BASIN

- SYSTEM OF THREE INTERLINKED, *EN-ECHELON* HALF GRABENS (EARLY-NEOGENE EXTENSION OVER THE IBERIAN RANGE)
- DEVELOPED IN A SEMIARID CLIMATIC CONTEXT OVER MOST OF ITS HISTORY
- INTERNALLY DRAINED UNTIL EARLY PLEISTOCENE



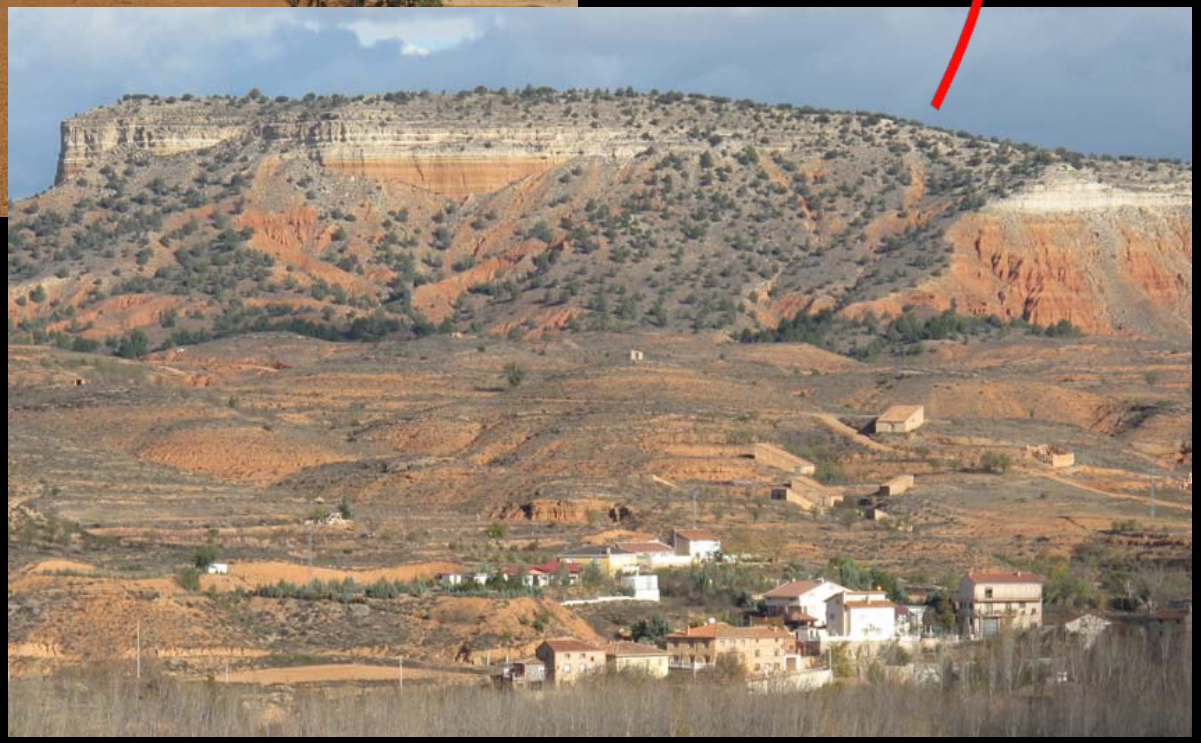


CLOSED BASIN FOR MOST OF ITS HISTORY IMPLIES:

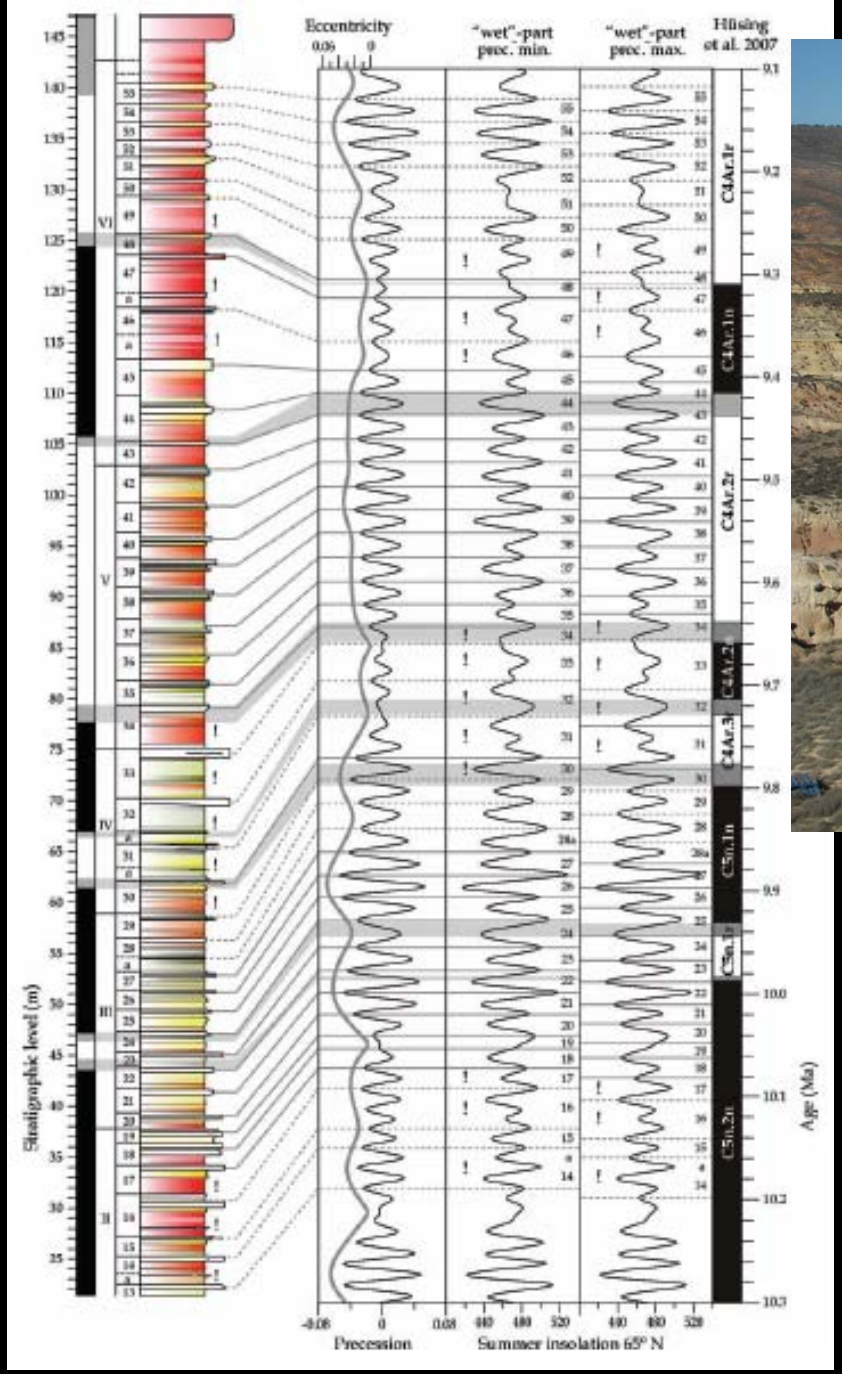
- ESSENTIALLY COMPLETE PRESERVATION OF STRATIGRAPHIC COLUMN
- FULLY AGGRADATIONAL ARCHITECTURE
- LONG-TERM ELEVATED SEDIMENTATION RATES

OUTCROP DISTANCE

~ 14 Km



BASINWIDE "LAYER-CAKE" STRATIGRAPHIC PATTERNS



EXAMPLE: *PRADO SECTION*

~ 200m OF MUDFLAT AND EPHEMERAL LACUSTRINE SEDIMENTS

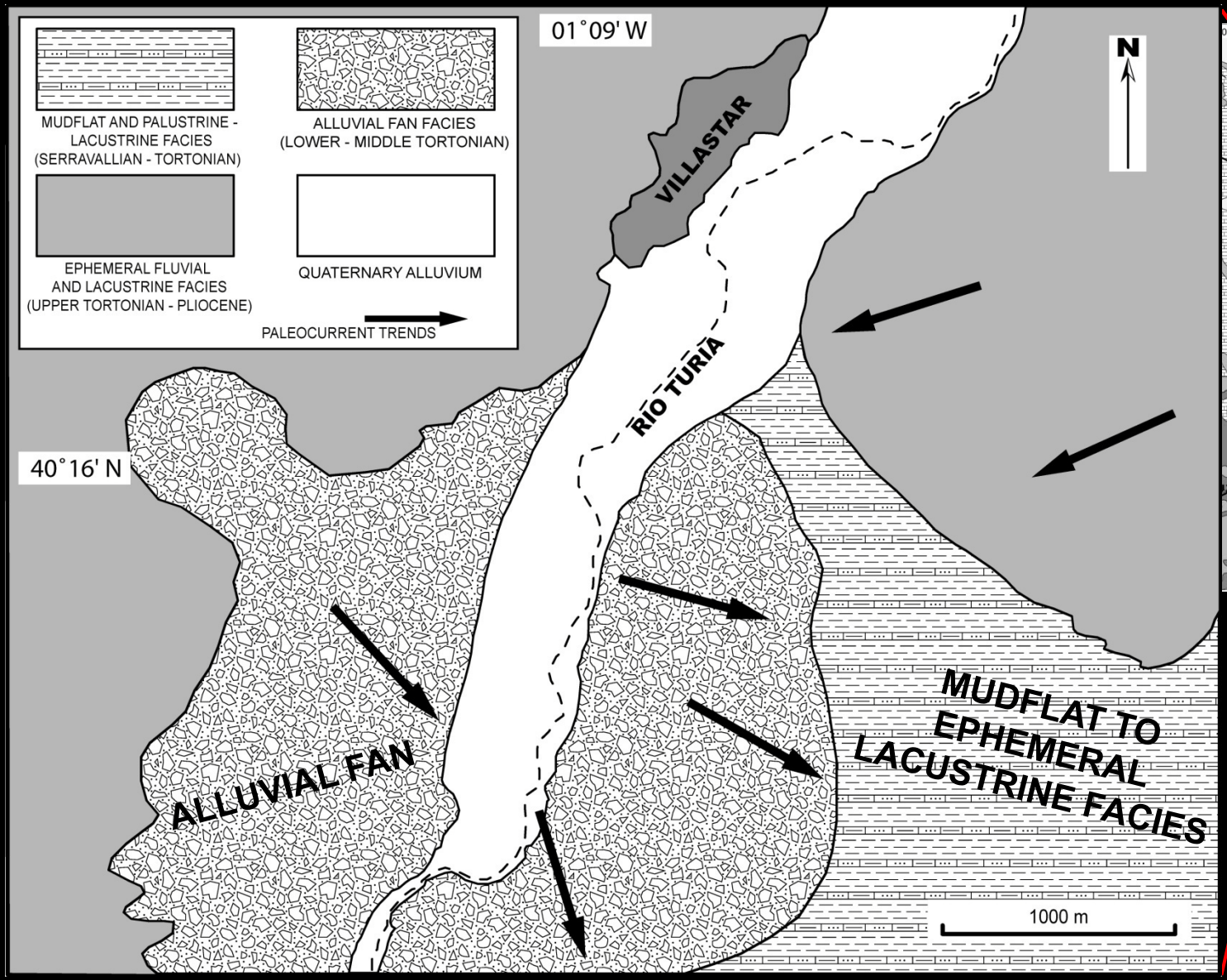
CHRONOSTRATIGRAPHICALLY COMPLETE, TUNED TO ASTRONOMICAL CYCLES

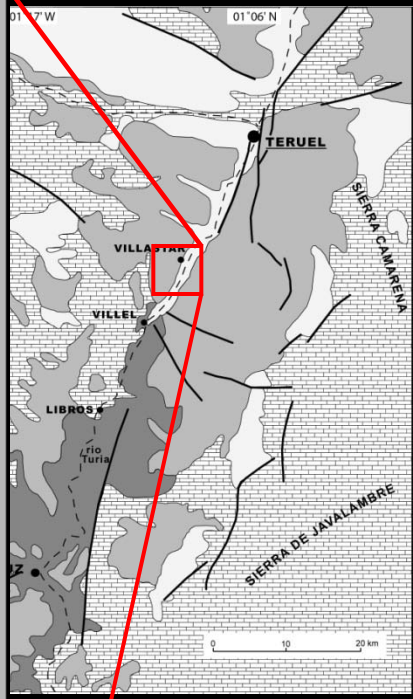
PRESERVES "SUBMILANKOVITCH" CLIMATE SIGNALS

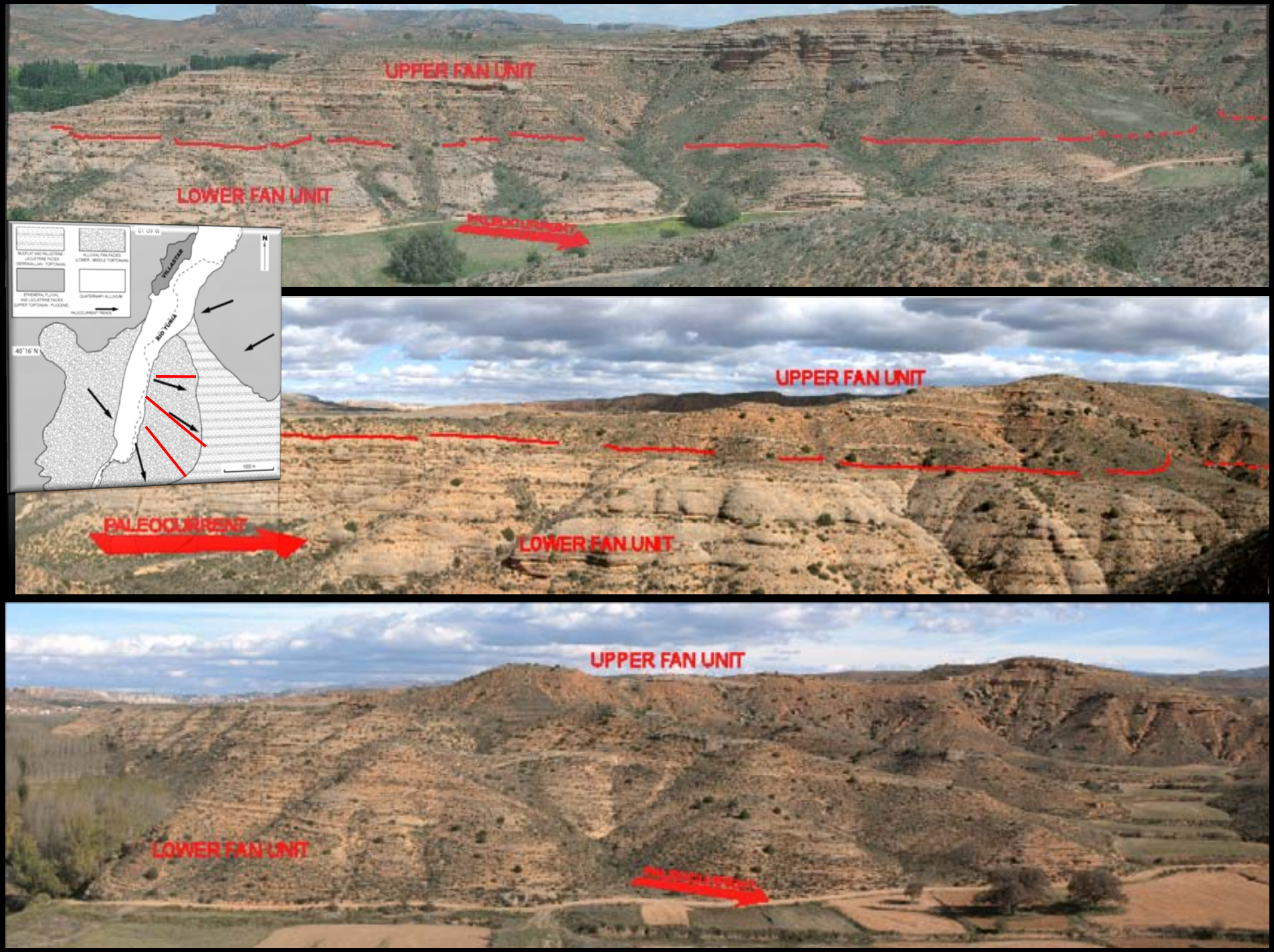
AVERAGE SEDIMENTATION RATE: 1mm / dy

ABELS et al. (2009, *JOURNAL OF SEDIMENTARY RESEARCH*)

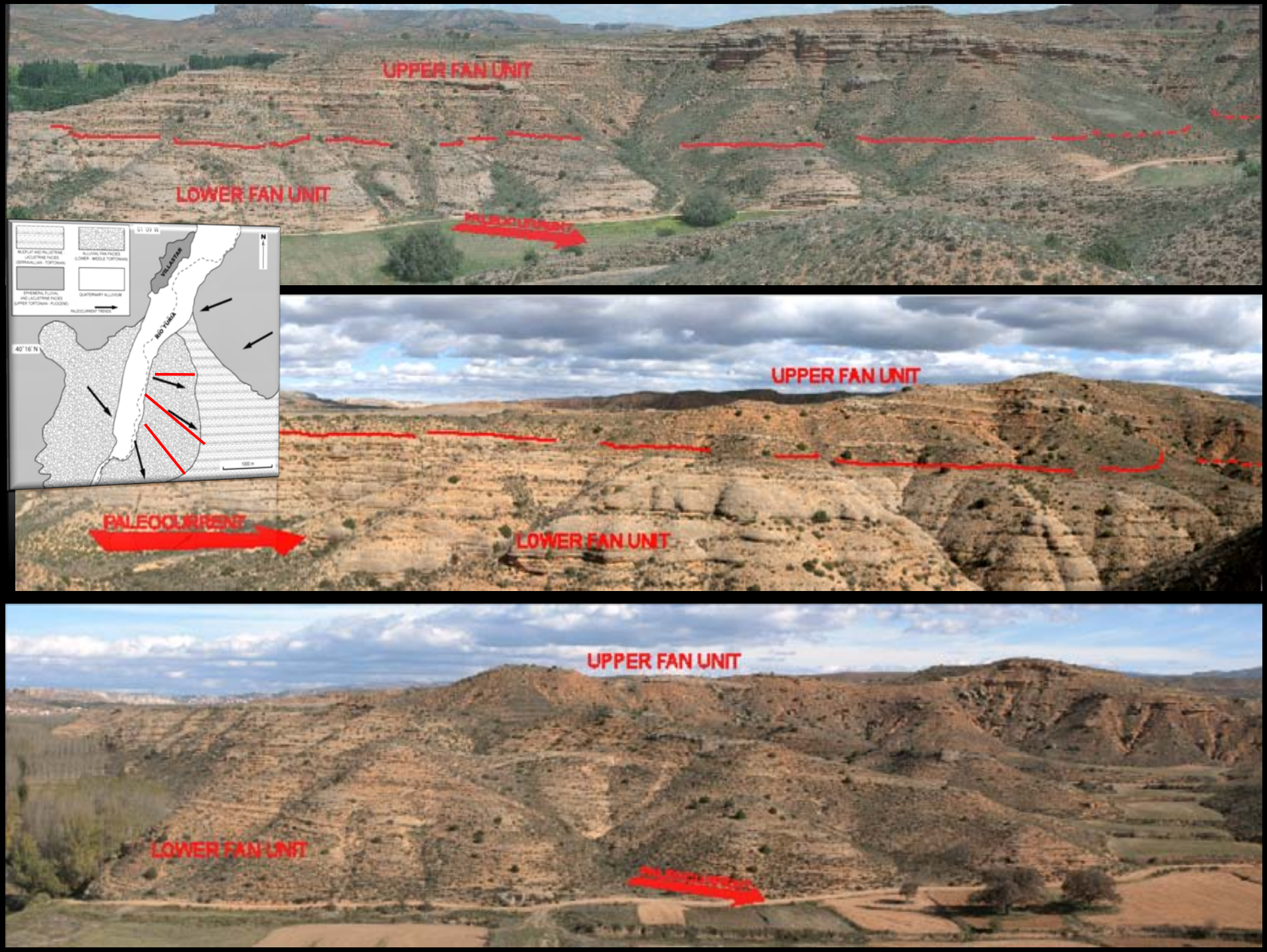
FACIES DISTRIBUTION IN THE MIDDLE SEGMENT OF THE BASIN PRESENTS A TYPICAL PATTERN FOR CONTINENTAL HALF-GRABENS





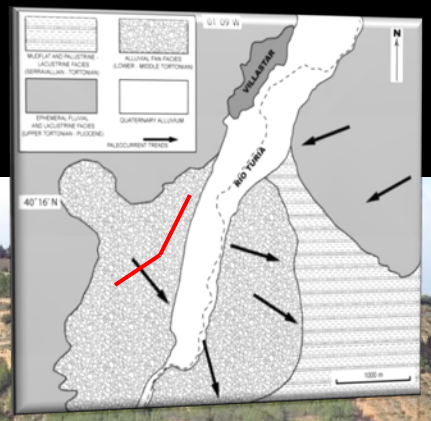

UPPER FAN UNIT
LOWER FAN UNIT
PALEOCURRENT
UPPER FAN UNIT
LOWER FAN UNIT
PALEOCURRENT
UPPER FAN UNIT
LOWER FAN UNIT
PALEOCURRENT
01° 09' W
40° 16' N
N
VILLASTAR
RÍO TURIA

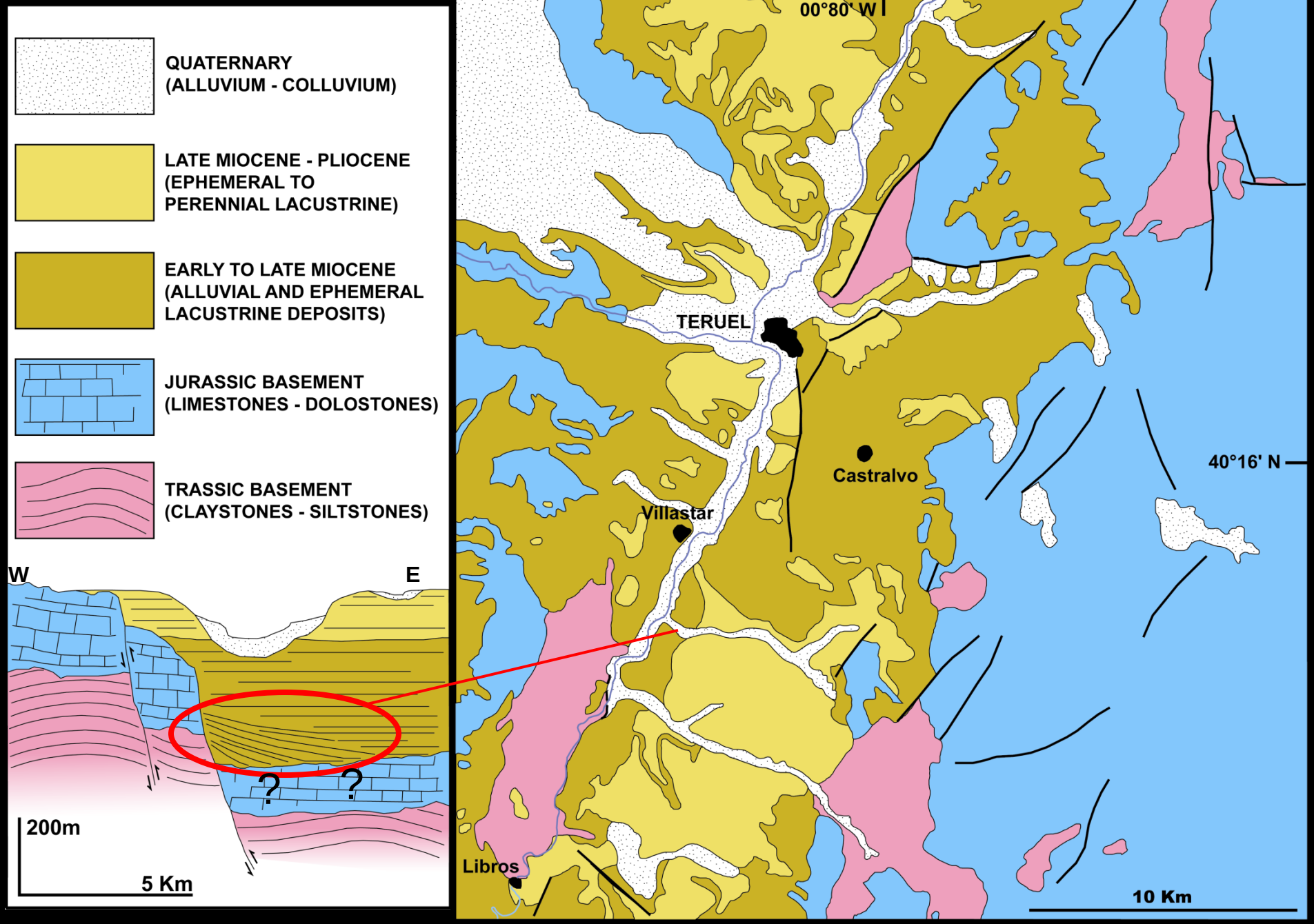
BASEMENT : TRIASSIC CONTINENTAL MUDSTONES, UNCONFORMABLY OVERLAIN BY MID-JURASSIC TO CRETACEOUS MARINE CARBONATES AND MARLSTONES


UPPER FAN UNIT
LOWER FAN UNIT
PALEOCURRENT
0° 09' W
N
VILLASTAR
RÍO TURIA
40° 16' N
UPPER FAN UNIT
PALEOCURRENT
LOWER FAN UNIT
UPPER FAN UNIT
LOWER FAN UNIT

PROXIMAL OUTCROPS

NO EVIDENCE OF INCISION




QUATERNARY
(ALLUVIUM - COLLUVIUM)
LATE MIOCENE - PLIOCENE
(EPHEMERAL TO
PERENNIAL LACUSTRINE)
EARLY TO LATE MIOCENE
(ALLUVIAL AND EPHEMERAL
LACUSTRINE DEPOSITS)
JURASSIC BASEMENT
(LIMESTONES - DOLOSTONES)
TRASSIC BASEMENT
(CLAYSTONES - SILTSTONES)
W
E
?
?
200m
5 Km
00°80' W
TERUEL
Castralvo
Villastar
40°16' N
Libros
10 Km

REFERENCE CONCEPTUAL MODEL

BASE-LEVEL "BUFFERS AND BUTTRESSES"

(Holbrook et al., 2006, Journal of Sed. Research)

Upper Buffer Profile
Transport Capacity = Min
Sediment Influx = Max
Uplift Rate = Max

Lower Buffer Profile
Transport Capacity = Max
Sediment Influx = Min
Uplift Rate = Min

Buffer Zone

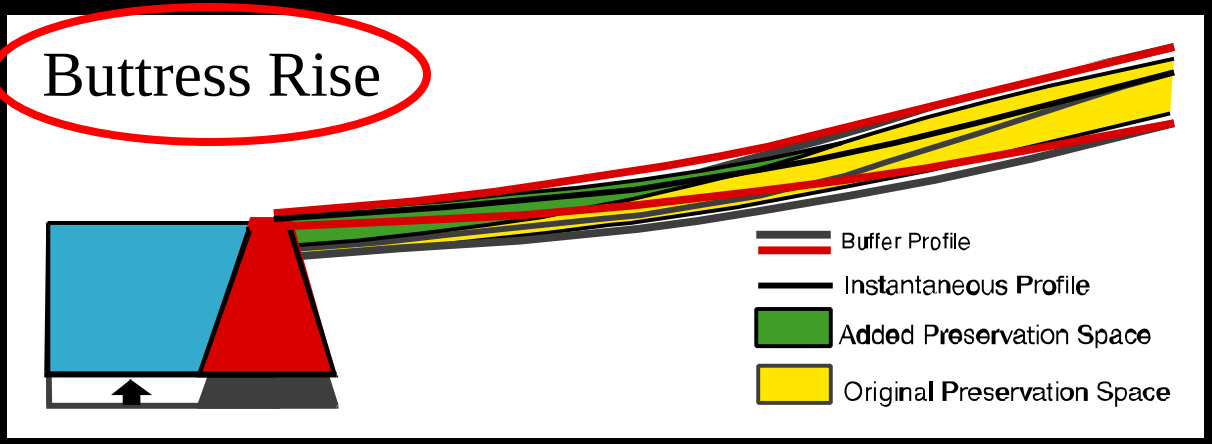
Buffers
f(Qw)

Preservation Space

Sea Level

BUTTRESS
(Sea Level, Cataract,
Lake Level, etc.)

RAISING BASE-LEVEL DOWNSTREAM (BUTTRESS) CONTINUOUSLY RAISES GRADED ALLUVIAL SURFACES (BUFFERS) UPSTREAM ALONG SYSTEM'S EXTENT

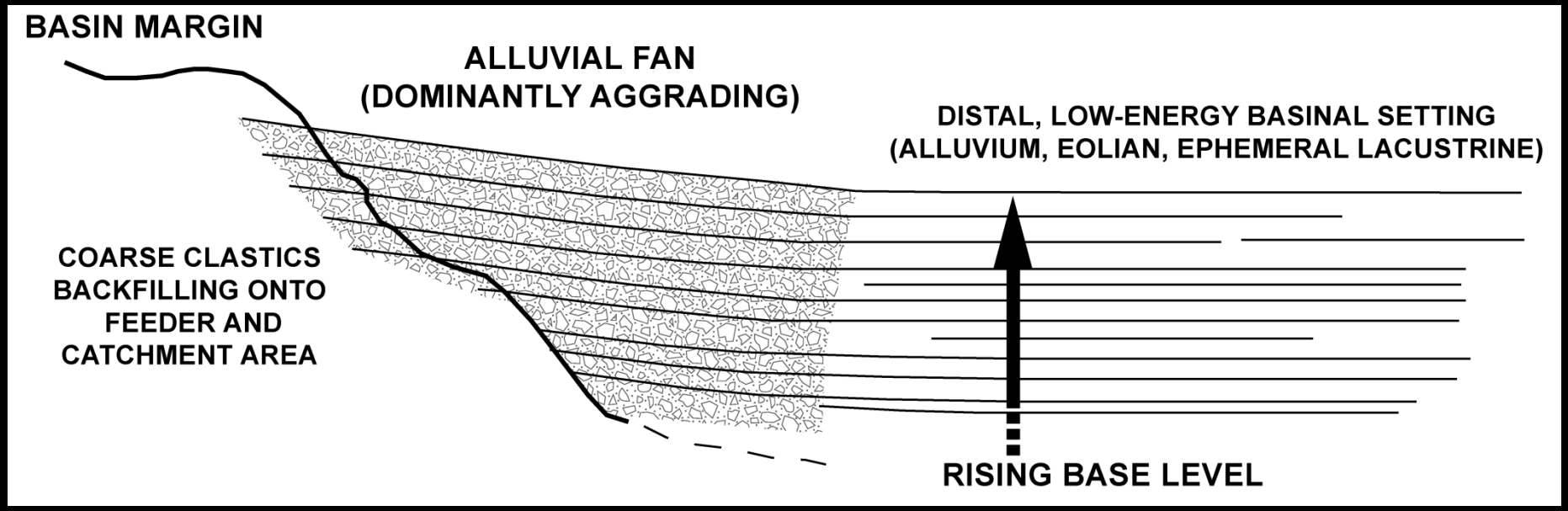


THE SCENARIO OF A STEADILY AGGRADING ALLUVIAL FAN:

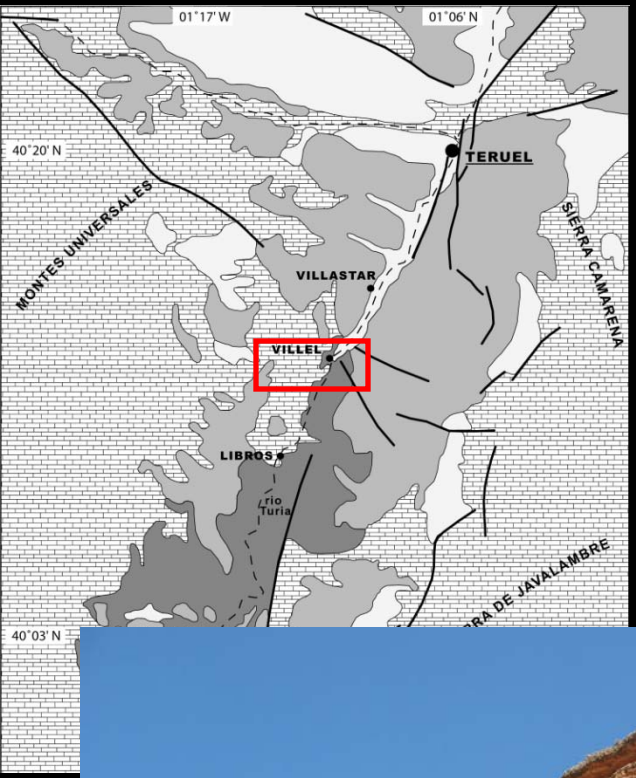
TOPOGRAPHICALLY CLOSED BASINS PREVENT SIGNIFICANT SEDIMENT BYPASS AND PROMOTE GENERALIZED AGGRADATION…

…WHICH IN TURN FORCES MARGINAL CLASTIC SYSTEMS TO RESPOND IN THE SAME WAY!

BACKFILLING OF MARGINAL TOPOGRAPHY MIGHT FOLLOW IF CLASTIC SYSTEM'S LIFESPAN IS SUSTAINED



ADAPTED FROM NICHOLS, 2005



ONE MORE EXAMPLE FROM VILLEL, 10 Km TO THE SOUTH ALONG THE SAME BASIN MARGIN

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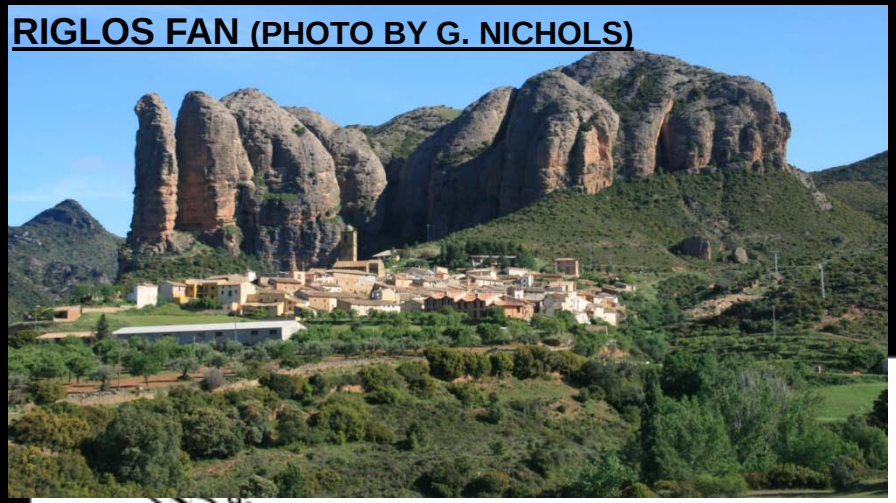
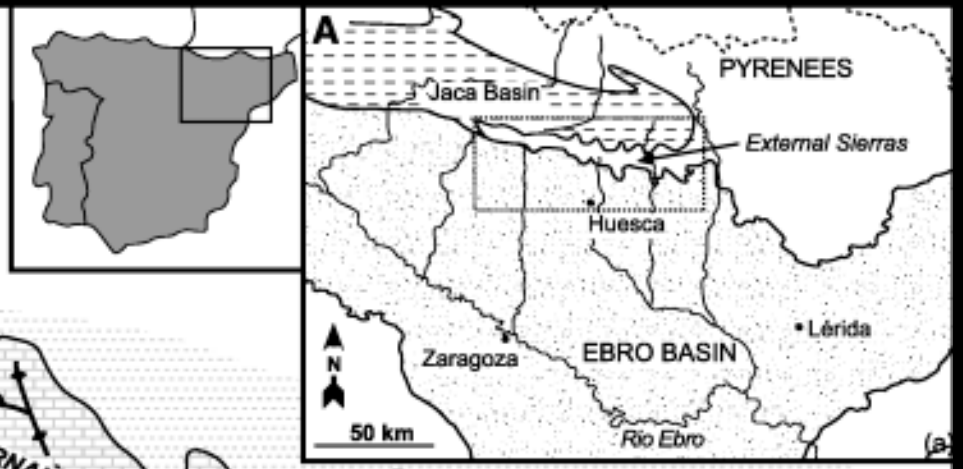
- CONCLUSIONS

RIGLOS FAN (PHOTO BY G. NICHOLS)



EBRO BASIN

ANALOG EXAMPLES, ON A LARGER SCALE, HAVE BEEN WORKED OUT BY G. NICHOLS ALONG THE NORTHERN MARGIN OF THE EBRO BASIN (NORTHERN SPAIN)



from LLOYD, NICHOLS & HIRST, 1998
JOURNAL OF SEDIMENTARY RESEARCH

PERFECTLY AGGRADATIONAL ARCHITECTURE OF CONFORMABLY TABULAR STRATASETS, WITHOUT INTERVENING LARGE-SCALE EROSIONAL SURFACES OR IN-SET ARCHITECTURES

ROLDAN FAN (PHOTOS BY G. NICHOLS)

- ALLUVIAL FAN RESEARCH…
- …AND THE POSSIBLY OVERLOOKED ROLE OF AUTOGENIC PROCESSES IN FIELD STUDIES
- TERUEL BASIN: EXAMPLES AND RATIONALE
- EBRO BASIN: ANALOGUES
- CONCLUSIONS

CONCLUSIONS

ANALOGUE-EXPERIMENTAL RESEARCH SUGGESTS THAT COMPLEX AUTOGENIC DYNAMICS IN ALLUVIAL FANS MIGHT BE FLYING WELL BELOW OUR SEDIMENTOLOGICAL RADAR, YET BE LEAVING SIGNATURES WE ARE NOT YET SURE HOW TO RECOGNIZE IN THE ROCK RECORD

THERE ARE BASINAL CONTEXTS IN WHICH WE CAN REASONABLY EXCLUDE A MAJOR ROLE FOR AUTOGENIC PROCESSES, AND THUS BETTER PINPOINT THE ROLE OF TECTONICS, CLIMATE AND CATCHMENT GEOLOGY

EXAMPLES FROM THE CONTINENTAL TERTIARY OF SPAIN POINT TO SUCH CONTEXTS TO BE CHARACTERIZED BY:

- TOPOGRAPHICALLY CLOSED BASINS WITH PERSISTENT ENDORHEIC DRAINAGE IN A TECTONICALLY ACTIVE SETTING
- RELATIVELY HIGH SEDIMENTATION RATES AND PRESERVATION POTENTIAL FOR DISTAL, BASINAL FACIES ASSOCIATIONS, FORCING A CONTINUOUS RISE IN ALLUVIAL BASE-LEVEL

THANKS TO:

GARY NICHOLS (Royal Holloway, University of London) for discussions and sightseeing guidance in the Ebro

NWO (National Science Foundation, The Netherlands) for research grants…

…and MIKE BLUM (Exxonmobil Upstream Research, Houston), for lively (and somewhat foodsome…) dinner discussions that ended up with a trip to New Orleans