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OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE PRESIDING OFFICER

In the Matter of	)	
	)	Docket No. 40-8968-ML
HYDRO RESOURCES, INC.	)	
2929 Coors Road, Suite 101	)	(Leach Mining and Milling License)
Albuquerque, New Mexico 87120	)	

NRC STAFF'S RESPONSE TO HRI'S
ANSWER TO PRESIDING OFFICER'S QUESTION

The Presiding Officer's unpublished order dated April 21, 1999 ("Memorandum and Order (Questions)") (April 21 Order)), contained eight questions, the last of which asked whether an article published in the geology literature said anything about how wide channels were in the Westwater sandstone near HRI's Church Rock site. *See* April 21 Order, at 4, ¶ 8. The referenced article, a 1991 paper authored by E. Jun Cowan, is discussed in Exhibit L to the January, 1999 affidavit of Dr. Richard Abitz,[1] submitted by Intervenors Eastern Navajo Diné Against Uranium Mining (ENDAUM), and Southwest Research and Information Center (SRIC).

On May 11, 1999, Hydro Resources, Inc. (HRI) filed its answers to the Presiding Officer's eight questions (HRI's May 11 Answers), pursuant to the April 21 Order, at 4, ¶ 1. HRI included

[1] Abitz Exhibit L contains four sets of 1994 comments on the Staff's draft environmental impact statement for HRI's proposed *in situ* leach mining project in New Mexico, and is apparently the "Exhibit L" which the Presiding Officer's question 8 references. The Cowan article is briefly discussed on page two of the second set of comments, made by the Navajo Nation Department of Water Resources Management, and dated December 29, 1994.

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a discussion of the Cowan paper in responding to question 8 of the April 21 Order. *See* HRI's May 11 Answers, at 39-41.

Pursuant to the April 21 Order, at 4, ¶ 3, the Staff's response to HRI's discussion of the Cowan paper is included in the affidavit of William Ford, attached hereto as Staff Exhibit 1.

Respectfully submitted,

John T Hull

John T. Hull
Counsel for NRC Staff

Dated at Rockville, Maryland
this 25th day of May, 1999

Staff Exhibit 1

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NUCLEAR REGULATORY COMMISSION

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HYDRO RESOURCES, INC.	)	Docket No. 40-8968-ML
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Albuquerque, New Mexico 87120	)	

AFFIDAVIT OF WILLIAM H. FORD

I, William H. Ford, being duly sworn, declare as follows:

1. I am competent to make this affidavit, and the factual statements herein are true and correct to the best of my knowledge, information, and belief. The opinions expressed herein are based on my best professional judgment. I have filed several affidavits in this proceeding, and my relevant expertise is summarized therein.

2. In preparing this affidavit, I reviewed the following materials: (1) question 8 of the Presiding Officer's unpublished order dated April 21, 1999; (2) a 1991 paper, authored by E. Jun Cowan, titled "The Large-Scale Architecture of the Fluvial Westwater Canyon Member, Morrison Formation (Upper Jurassic), San Juan Basin, New Mexico" (Cowan Paper), as published in *Concepts In Sedimentology and Paleontology*, volume 3, at pages 80-93 (excerpts referenced below are attached hereto as Ford Attachments A-D); and (3) a discussion of the Cowan Paper, set forth in the May 11, 1999, Hydro Resources, Inc. (HRI) filing (HRI's May 11 Answers), at pages 39-41. This affidavit is based on these reviews.

3. Cowan's Paper is focused on investigating the question of whether the thick sandstone beds of the Westwater Canyon Member contain channel systems, as described by C.

Campbell in a 1976 paper. *See* Cowan Paper, at page 80, col. 2 (Ford Attachment A). Cowan concludes that the individual channel systems identified by Campbell are not individual channel systems, but are post-depositional pore-water conduits, each composed of several sandstone sheets or bodies, having 15 to 33 foot thicknesses. *Id.*, and page 89, col. 3 (Ford Attachment B).

4. More significantly, for purposes of answering the Presiding Officer's question 8, Cowan states that these sandstone sheets have widths, at a minimum, of one kilometer (one kilometer equals 0.6 miles). *See* Cowan Paper abstract, at page 80, col. 1, and page 93, Figure 18 caption (Ford Attachment C). *See also* Figure 17 (Ford Attachment D).

5. Both Campbell's 1976 description, and Cowan's 1991 description, of the Westwater Canyon aquifer, are consistent with the description given in the FEIS, at page 3-14, and with the following statements in my February 20, 1998, affidavit, filed in this proceeding:

> The Westwater Canyon aquifer is not a homogeneous aquifer. Rather, as is true for almost all uranium deposits on which ISL mining is used, the uranium deposits here are sandstone aquifer deposits of fluvial (stream-deposited) origins, interbedded with siltstones, shales, and mudstones.

February 20, 1998, affidavit, at ¶ 8.

> The Westwater Canyon is best described as thick sand units that are hydrologically interconnected vertically and horizontally, as individual siltstone, shale, and claystone layers pinch out.

February 20, 1998, affidavit, at ¶ 9.

6. I agree with HRI (*see* HRI's May 11 Answers, at page 41) that the Cowan Paper's description of the Westwater Canyon Member as being made up of coalesced or amalgamated sandstone sheets, precludes the existence therein of confined, elongated channels, of the type posited

by the Intervenors' experts. Accordingly, I conclude that the Cowan Paper further invalidates the Intervenors' sand channel theory.

7. The statements expressed above are true and correct to the best of my knowledge, information and belief.

William H. Ford

William H. Ford

Sworn and subscribed to before me
this 24th day of May, 1999

Malinda L. McDonald

Notary Public
My commission expires: 12/1/2001

THE LARGE-SCALE ARCHITECTURE OF THE FLUVIAL WESTWATER CANYON MEMBER, MORRISON FORMATION (UPPER JURASSIC), SAN JUAN BASIN, NEW MEXICO

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ABSTRACT: The Westwater Canyon Member of the Morrison Formation (Upper Jurassic) has previously been interpreted as consisting of fluvial "channel systems" tens of kilometers wide and tens of meters thick. Reinvestigation of the member indicates that these "channel systems" actually represent post-depositional aquifer conduits, defined instead by differing sandstone colors, rather than primary depositional features. The member is composed of amalgamated, individual fining-up sandstone sheets each about 5-10 m thick. The absolute widths of these sheet sandstone bodies are at least 1 km and possibly exceed several kilometers. The width:thickness range of the sandstone sheets are well within the typical values of sandstone body dimensions reported from other fluvial sandstones, and are interpreted to represent aggradational channel-belts. Sandstone bodies thicker than about 12 m are the result of amalgamation of these individual unit sandstone bodies, and do not represent individual channel belts as interpreted previously.

Internally, the sheets contain abundant concave-up troughs typically 30 m wide and 5 m thick, filled both laterally and vertically with inclined parallel- to low-angle cross-stratified sandstone, in places exhibiting parting lineation. The laterally-limited extent of these large troughs and nature of their internal fills suggest that they represent short-lived scour fills rather than confined elongated channels. The concave-up erosional base, a negative feature, was most likely formed due to large-scale flow separation within a wider and shallower channel. Physical conditions similar to stream-flow convergence at channel confluences may be responsible for their formation. The abundant preservation of these troughs in the Westwater Canyon Member is consistent with the expected poor preservation of positive barforms in a sweeping, sandy-braided channel belt.

Review of the literature indicates that inferred channelbelt sandstone bodies mostly fall within the thickness range of 1 to 12 m, irrespective of their interpreted fluvial style. Post-depositional large-scale reservoir conduits are also expected to fall within this range for sandy fluvial systems. Deviations from this range are due to amalgamation of the sandstone bodies or increased grain-size heterogeneity, resulting in an increase and decrease, respectively, of the conduit size.

INTRODUCTION

[PAGE 80
COL. 1]

Clarifying the origin and post-depositional burial history of fluvial-sandstone bodies is critical to understanding the scale and role of heterogeneities involved in the migration of pore fluids following the burial of sandy fluvial deposits (cf. Miall, 1988b). The architecture of sandstone bodies resulting from channelbelt avulsion and coeval basinal subsidence has been modeled quantitatively by several workers (Alexander and Leeder, 1987; Allen, 1978, Bridge and Leeder, 1979; Leeder, 1978). These quantitative models are able to predict depositional patterns resulting from syndepositional subsidence and repeated avulsion of channel belts. The resulting architecture of the sandstones controls the pore-fluid flow, and hence influences hydrocarbon migration and the emplacement of some eco[illegible]ic metalliferous ores, such as uranium. Application of these models require[illegible]ield recognition of individual channelbelt deposits. There are, however, few[illegible] descriptions in the fluvial literature, especially those of sandy multichannel fluvial systems, which differentiate individual channel belts from laterally and vertically interconnected channelbelt deposits.

One of the best-known examples of the documentation of alluvial architecture is that of Campbell (1976) on the Upper Jurassic Westwater Canyon Member of the Morrison Formation, San Juan Basin, New Mexico. Campbell's work has been extensively cited as a typical example of a braided river deposit involving the preservation of laterally coalesced "channel systems" and "smaller channels" and has been repeatedly used in textbooks (e.g., Cant, 1978; Leeder, 1982; Collinson, 1986). These "channel systems" were described by Campbell (1976) to be vertically and laterally coalesced, and to range in width from 1.6 to 34 km and in thickness from 6 to 61 m. Individual "smaller channels" have widths of 30 to 366 m and depths from 1 to 6 m (Campbell, 1976).

On the basis of detailed outcrop studies, this paper shows that the "channel systems" of Campbell (1976) do not represent depositional channels, but are post-depositional aquifer conduits or permeability-pathway compartments. The conduits (identified on the basis of color, which reflect the state of sandstone oxidation) are up to several tens of meters thick, and were formed by the vertical coalescence of sandstone sheets about 5-10 m in thickness, interpreted here to represent channelbelt deposits. The sheets are internally composed of large concave-up features ("smaller channels" of Campbell, 1976) which are interpreted to represent large scour fills produced in a wide braided channel belt.

GEOLOGICAL OVERVIEW

The Upper Jurassic Morrison Formation was deposited in the San Juan Basin (Figs. 1a, b) which lay several hundred kilometers east of a Late Jurassic Andean-

[PAGE 80, COL. 2]

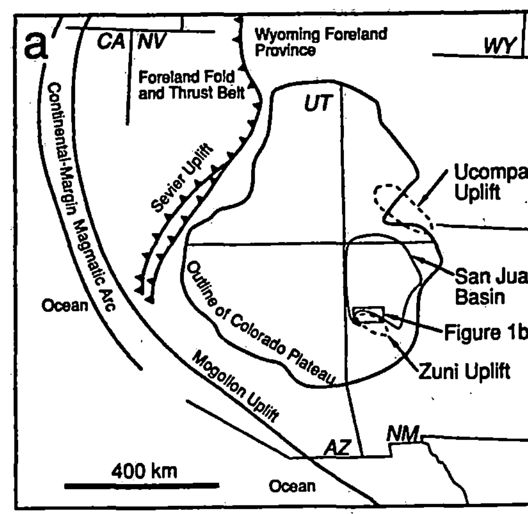

FIG. 1.—a. Location of the study area in a basinal context. The study area enclosed in the rectangle is detailed in b. Modified from Santos and Turner-Peterson (1986, Fig. 3). b. Study area with positions of the lateral profiles used to construct Fig. 6 shown as black bars. Numbers refer to the measured sections of C[illegible]pbell, also shown in Fig. 3. Detailed map of the Kit Carson's Cave area, [illegible]n enclosed, is illustrated in Fig. 4. White Rock Mesa is labeled as '[illegible]'. Map borders parallel UTM grid. Geology from Hackman and Olson (1977).

dimensions as documented by Campbell (1976) is expected if amalgamation of more regular channelbelt deposits occurs at random (cf. Bridge and Leeder, 1979, see their Figs. 2c and 4c).

Cliff exposures of the Westwater Canyon Member serve as an excellent example for illustrating the control of overbank fines as effective barriers to pore-fluid flow. It is apparent that on the member scale, the preservation of overbank-fine deposits between sheet-like sandstone bodies has controlled the pore-fluid flow, notwithstanding the internal complexity of the sheet-sandstone architecture as revealed by the detailed lateral profiles. The sheet sandstones, with very little internal grain-size variation, acted as fluid conduits, and the thicknesses of conduits or compartments were solely dependent upon the preservation of overbank fines between the interpreted channelbelt sandstone bodies. The review of published examples of fluvial-body dimensions indicates a consistency of sandbody thicknesses, namely in the 1- to 12-m range, and the thicknesses of the Westwater sheets fit in this range (Fig. 17). The pore-fluid flow, therefore, will be largely confined within this thickness for sandy fluvial systems. Increases in this thickness range will be the result of amalgamation of the unit sandstone sheets by erosion of capping overbank fines, whereas a decrease is likely to be associated with increasing heterogeneity of grain size within the sandstone channelbelt bodies (as in deposits resulting from mixed-load fluvial systems).

FORD ATTACHMENT B

Implications of hollow preservation

Fluvial sedimentologists have concentrated on the sedimentary features formed from the migration of positive barforms, and used these structures to decipher styles of fluvial sedimentation (Allen, 1983b; Haszeldine, 1983; Miall, 1988a). Little attention has been directed to processes in the deepest portions of fluvial channels until only recently (e.g., Best and others, 1989). Theoretically, it is not considered possible to preserve the entire thickness of the channelbelt deposit, and entire macroforms, unless avulsion of the channel belt takes place (cf. Bridge and Leeder, 1979). However, scour-fill processes, as documented by workers such as Best (1987) and Cant (1976), are comparatively more ephemeral, in a multichannel fluvial system, than life of constructional macroforms; it is likely that these structures with high preservation potential deposited in the deepest parts of the channel belts may dominate the geological record. The abundant hollows as seen in the Westwater Canyon Member may represent such scours from the deepest portions of the channel belt.

CONCLUSIONS

[PAGE 89, COL. 3]

Several significant conclusions can be drawn from this study of the large-scale features of the Westwater Canyon Member.

1. The "channel systems" described by Campbell (1976, Fig. 3 herein) are not channelbelt deposits but records of post-depositional pore-water conduits composed of amalgamated, ~5- 10-m-thick sheet sandstone bodies.

2. The individual sheet-sandstone-body thickness of the Westwater Canyon Member falls within the thickness ranges of sandstone bodies that are of possible channelbelt origin. Sandstone body thicknesses in excess of 12 m appear to result from channelbelt amalgamation.

3. Diagenetic pore-fluid flow was primarily controlled by the presence of thick overbank deposits which escaped erosion during amalgamation of channelbelt sandstone bodies. Published data on fluvial deposits indicat[illegible]arge-scale pore-fluid conduits composed of homogeneous channelbelt sandb[illegible]all within the 1-12 m thickness range. Departures from this range are expected to be due either to channelbelt amalgamation or higher heterogeneity within the sandstone sheet.

4. Internally, sheets display trough-like features ~30 x 5 m in cross-section dimensions, commonly isolated, with varying orientations of internal fill. The interpretation of these large-scale hollow features is most consistent with a scour produced within the deepest portions of a shallow, braided-fluvial environment, possibly due to channel-confluence scouring. The variable inclination of the fills, with parting lineation on their bedding surfaces, are most consistent with a rapidly filled scour and are less consistent with forms produced from trains of large dunes or small channels, as previously interpreted.

5. The member contains low-amplitude, laterally extensive macroforms bounded by flat erosional surfaces, consistent with the interpretation that the style of the fluvial environment was a braided multichannel system. Hollows, on the other hand, are bounded by concave-up erosional surfaces and are interpreted to have been produced in the deepest portions of the fluvial channel belt, and hence have greater preservation potential than constructional macroforms.

ACKNOWLEDGMENTS

This work was completed while the author was the recipient of a Canadian Commonwealth Scholarship. Acknowledgment is made to the donors of the American Chemical Society Petroleum Research Fund, AAPG Grants in Aid, and to NSERC for support of this project through research grants to my supervisor A.D. Miall. I thank the Navajo Nation (Window Rock, AZ) for allowing field work to be conducted on the Navajo Indian Reservation. I am indebted both to Andrew Miall who initially suggested reexamining the large-scale architecture of the Westwater Canyon Member, and to Christine E. Turner-Peterson whose guidance in and out of the field was most appreciated. Andrew D. Miall, Greg C. Nadon, Alan C. Kendall, Nick Eyles and Paul D. Godin (who also assisted in the field) are thanked for stimulating discussion and comments on the manuscript during various stages of the study. Constructive criticism by reviewers C. E. Turner-Peterson and A. Ramos served to greatly improve the manuscript. The oblique aerial photographs used to construct Figures 5 and 6 were photographed by A.D. Miall and reproduced by Brian O'Donovan.

[PAGE 89, COL. 4]

REFERENCES

Alexander, J., and Leeder, M. R., 1987, Active tectonic control on alluvial architecture, *in* Ethridge, F. G., Flores, R. M., and Harvey, M. D., eds, Recent developments in fluvial sedimentology: Society of Economic Paleontologists and Mineralogists Special Publication 39, p. 243-252.

Allen, J. R. L., 1978, Studies in fluviatile sedimentation: An exploratory quantitative model for the architecture of avulsion-controlled alluvial suites: Sedimentary Geology, v. 21, p. 129-147.

________, 1983a, Gravel overpassing on humpback bars with mixed sediment: examples from the Lower Old Red Sandstone, southern Britain: Sedimentology, v. 30, p. 285-294.

________, 1983b, Studies in fluviatile sedimentation : bars, bar-complexes and sandstone sheets (low-sinuosity braided streams) in the Brownstones (L. Devonian), Welsh Borders: Sedimentary Geology, v. 33, p. 237-293.

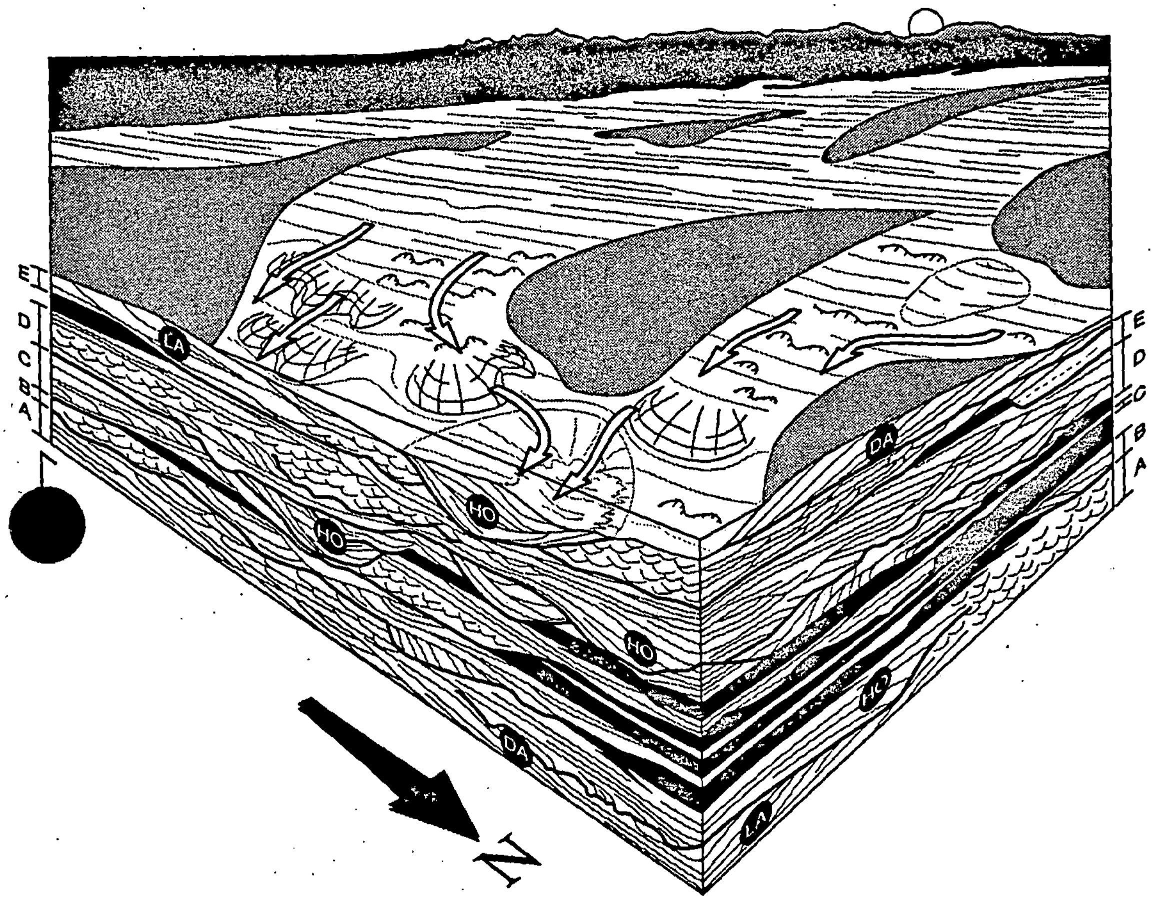

FIG. 18.–The large-scale architectural model of the Westwater Canyon Member fluvial system. The block diagram illustrates waning-stage flow, seen looking toward the southwest and the Late Jurassic magmatic arc. The sandstone units produced between each avulsive event of the channel belt are approximately 5 m thick, and are bounded by laterally-extensive fifth-order bounding surfaces. The width of the sandstone sheets is most likely >1 km. The sandstone bodies can be either single or composite channelbelt sandstones, depending on their vertical stacking, as shown by the examples of sandstone sheets A to E. The large hollows (labelled HO) within the sandstone sheets are interpreted as channel-confluence scours produced downstream of emergent channel sand bars, which in turn produce low-amplitude lateral accretion (LA) and downstream accretion (DA) deposits.

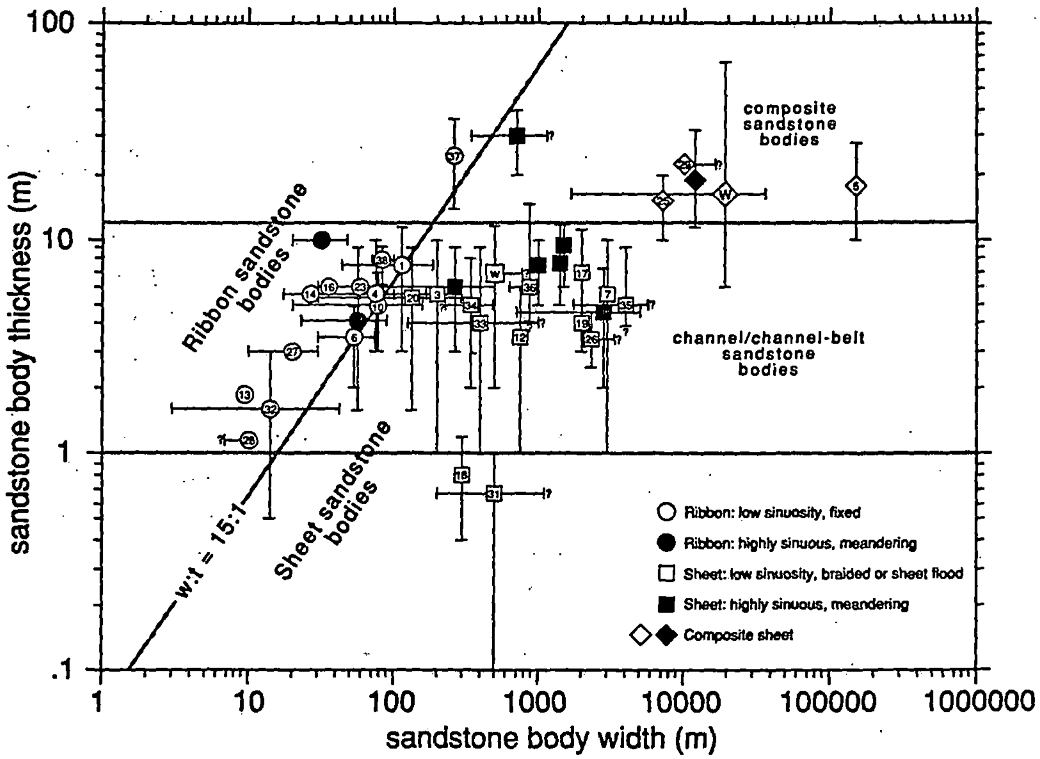

FIG. 17.–Log/log plot of published width:thickness dimensions of sandstone bodies, with ranges indicated by the bars. Published data which did not indicate ranges are not plotted with bars. Sources as follows: 1 and 2, Abrahamkraal Fm., Stear (1980); 3-6, Chinle Fm., Blakey and Gubitosa (1984), width ranges of 4 and 6 estimated assuming width:thickness ratio of 15:1; 7 and 8, Castissent Fm., Marzo and others (1988); 9, Middle Siwalik, Behrensmeyer and Tauxe (1982); 10 and 11, Scalby Fm., Nami and Leeder (1978); 12, Ft Prevel Fm., Lawrence and Williams (1987); 13 - 16, Oligocene and Miocene of Ebro Basin, Friend and others (1979); 17 - 19, Brownstones, Tunbridge (1981); 20 and 21, Salt Wash Member, Morrison Fm., Peterson (1984), width ranges of 22 estimated assuming width:thickness ratio of 15:1; 22 - 24, Willwood Fm., Kraus and Middleton (1987); 25, George West Axis, Oakville Fm., Galloway (1981); 26 and 28, Archer City and Nocona Fms., Sander (1989); 29, Beaufort Fm., Turner and Whately (1983); 30, McMurray Fm., Mossop and Flach (1983); 31, 32 and 33, sheet, simple and multistorey sandbodies respectively, Dinosaur Canyon Mbr, Moenave Fm., Olsen (1989); 34, 35 and 36, Jarillal, Huachipampa and Quebrada del Cura Fms., Beer and Jordan (1989); 37, Lower Kootenai Fm., Hopkins (1985); 38, Waddens Cove Fm., Gibling and Rust (1990); W, "channel system" dimensions of the Westwater Canyon Member as given by Campbell (1976); w, estimated sheet sandstone body dimensions of the Westwater Canyon Member as presented herein, minimum width only, maximum not known.

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	)	Docket No. 40-8968-ML
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Albuquerque, New Mexico 87120	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of "NRC STAFF'S RESPONSE TO HRI'S ANSWER TO PRESIDING OFFICER'S QUESTION" in the above-captioned proceeding have been served on the following by U.S. Mail, first class, or, as indicated by a single asterisk through deposit in the Nuclear Regulatory Commission's internal mail system, or, as indicated by double asterisks, via e-mail and express mail, this 25th day of May 1999:

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