Langenberg et al. (2002) purport to identify discrete ‘channel complexes’ in outcrop exposures along the Steepbank River of northeastern Alberta, and they claim to have extrapolated these channel complexes into the nearby subsurface. They have used the resulting stratigraphic correlations as input for a seismic model constructed using ray-tracing techniques. The seismic model demonstrates the viability and utility of high resolution seismic over the shallow deposits of the Athabasca Oil Sands.

Two major issues in Langenberg et al. (2002) deserve comment, however.

1) The criteria that Langenberg and his colleagues use for differentiating ‘channel complexes’ is simplistic, ill-defined and of questionable validity. Their extrapolation of these ‘channel complexes’ into the subsurface is not supported. Furthermore, the interpretation of the relationship between ‘channel complexes’ from the outcrop face is blatantly incorrect. These factors account for many inconsistencies evident in the cross-sections presented by Langenberg et al. (2002) and discussed below.

2) Langenberg and his colleagues use a stratigraphic framework that is untenable and confusing. Their proposed changes to the informal stratigraphic subdivision of the McMurray Formation are uncalled for and ill-advised at this time.

The seismic modeling techniques used by Langenberg et al. (2002) do appear to support their conclusion, from a purely technical standpoint, that high-resolution seismic has evolved to become a useful tool for examining detailed stratigraphy within the McMurray Formation. However, multiple errors and inconsistencies in interpretation of the stratigraphy and sedimentology throw doubt on their depositional model. Therefore, the geology expressed in their seismic model is questionable and should not be used as a baseline example or a control for interpreting real seismic data in the surrounding area.
into the other, whose paleoflow and/or inclined master bedding could conceivably be oriented 90° or more apart. The dipmeter data from the Clarke Creek area (Langenberg et al., 2002, their Fig. 21) demonstrate this: a single seismically-defined ‘channel complex’ displays variable paleoflow directions with azimuth orientations varying by up to 90°. In fact, it is not difficult to imagine meanders developing on opposite sides of a channel with point bar master bedding dip directions opposed 180° from each other at different stages of development of a channel complex. Yet one could hardly argue that this is evidence for the existence of separate channel complexes. The term channel ‘complex’ implies more than just the manifestation of a single point bar deposit in a single channel. Arguably, a more likely interpretation is that laterally extensive IHS beds exposed within genetic units along the Steepbank River are discontinuous remnants of meander point bars developed within a single channel complex.

Because all of the paleoflow orientations presented by Langenberg et al. (2002) lie within a limited 90° arc, and given the expected variation in current direction and point bar master bedding in a meandering channel system, their Channel Complexes 2, 3 and 4 cannot be reliably differentiated by this criterion. Channel Complex 1 apparently has no paleocurrent data.

The correlation of these ‘channel complexes’ through the subsurface to wells that may be more than a kilometre away is also highly questionable. Langenberg et al. (2002) provide no criteria for extrapolating their channel complexes to the subsurface using well data, except for a statement in the abstract (p. 178) that “they are similar to exposed outcrops in the riverbank”. There were no dipmeters run in the wells around the Steepbank outcrops, and even if there were, the issues discussed above suggest that they would be of limited value for this purpose. In outcrop, facies within a channelized genetic unit are extremely variable. Our observations suggest that IHS sets may vary from sand-dominated to mud-dominated in just a short distance, both laterally and vertically. Major boundaries between channelized genetic units may be recognized by persistent horizons that separate distinct, and typically, discordant, geometric changes in bed morphology, marked by a widespread scour horizon. But the contrast in architecture is megascopic and commonly can only be observed from a perspective of some distance or from a panoramic photograph.

Correspondingly, within the limited dimensions of a core, major stratigraphic units can seldom be deduced with any confidence. They are not always marked by recognizable scour horizons, and they may or may not be marked by dramatic facies changes. And, vice versa, the presence of a dramatic facies change may not signal the base of a major genetic unit, but may simply be, for example, evidence for a seasonal fluctuation in flow velocity. Even where bounding horizons are suspected in core, the lateral extent and therefore the significance of the horizon can not be easily inferred from core to core as it can in the two dimensional extent of an outcrop face.

Langenberg et al. (2002) provide no evidence from core of a bounding horizon between any of their ‘channel complexes’. In fact, on the structural cross-sections (their Figs. 13, 14) only one well, AA/16-30-92-9, is shown to contain a contact between ‘channel complexes’, and no core is available for that well; only wireline logs. The criteria for interpreting a contact within that well is not given, and a contact is not obvious from wireline logs. All other wells are shown to penetrate only one channel complex, yet there are no criteria to demonstrate why they are assigned to a particular channel complex. Both core descriptions presented in the study (Langenberg et al., 2002, their Figs. 10, 11) are assigned to the same channel complex although few similarities exist between either the core descriptions or the wireline signatures (except that both become somewhat muddier upwards).

There are many instances where Langenberg et al. (2002) make unsupported interpretations. Their wireline log cross-section (their Fig. 15), which assigns all three wells to the same ‘Channel Complex 2’, dramatically demonstrates the difficulty of attempting to correlate channel complexes solely by wireline logs. The log signatures from the three wells are markedly different and indicate many dramatic facies changes at various stratigraphic levels. It is puzzling how these wells have all been assigned to Channel Complex 2. The same is true for the synthetics that Langenberg et al. (2002) use for the seismic model. For example, their Figure 17 shows synthetics from three wells, all of which penetrate Channel Complex 2. Yet the reflectors vary from well-defined, high amplitude in 14-29-92-W4 to transparent in outcrop 4, section 2. No obvious similarity exists between the synthetic seismograms, and there are no correlateable reflectors to suggest that these three wells are from the same channel complex.

In another example, Channel Complex 1 is interpreted from only one well and no outcrop (their Fig. 13). That well (AA/4-21-92-W4) has no core; only wireline logs. Despite the obvious problem that they do not provide any legitimate criteria for discriminating channel complexes from one another even where core is available, Langenberg et al. (2002) claim to be able to interpret from wireline logs alone that the 4-21 well represents a separate channel complex, and that Channel Complex 2 incises into the top of it, completely removing it somewhere in the subsurface. This scenario is speculative and unsubstantiated. Langenberg et al. (2002) do point out that the synthetic for the 4-21 well features “…low amplitude and locally transparent reflectors” (p. 195). However, given the variability in the distribution of facies within channel complexes (e.g. their cross-section Fig. 15), the synthetic alone (itself derived from the well logs) is of dubious value for differentiating channel complexes. Furthermore, Langenberg et al. (2002) state that the seismic reflectors over Channel Complex 1 are “parallel, low angle...” (p. 195). It is a mystery to us how this can be deduced from the synthetic from one well. Surely ray-tracing cannot model the structural orientation and configuration of strata given a single data point.

More troublesome is the relationship between ‘channel complexes’ that Langenberg et al. (2002) have interpreted from outcrop. The annotated photo of Outcrop 4 (their Fig. 12) showing ‘Channel Complex 3’ incising discordantly down into ‘Channel
Complex 2' is incorrect. The photo is taken from an oblique angle, and presumably it is that perspective that has led them to an incorrect conclusion. Their Complex 3 overlies Complex 2, but the contact is not an inclined, discordant, incision surface. Our Figure 1, a photo taken from the air and closely perpendicular to the outcrop face, demonstrates that the contact is more or less horizontal as far as it can be followed. To the south (left in the photo), the contact is covered by scree, but nowhere can it be seen to incise down discordantly into the underlying strata. Certainly the IHS beds overlying and underlying the contact dip in opposing apparent directions, and they are discordant in that regard, but the contact itself is more or less horizontal at this outcrop face. In fact, nowhere in any of the Steepbank outcrops have we observed deep incision of one channelized genetic unit into another resulting in its complete removal. All major contacts, marked by what appear to be significant erosional surfaces, are observed to be more or less horizontal or slightly undulating. Therefore, the channelized genetic units appear to be vertically stacked at the Steepbank River outcrops, not laterally cannibalized. We do not dispute that conceptually an incised geometry may be an integral part of internal McMurray Formation stratigraphy, however Langenberg et al. (2002) have failed to demonstrate its presence in their study area.

There are other inconsistencies in the figures. The East–West cross-section (Langenberg et al., 2002, their Fig. 13) is misleading and questionable, since several of the wells projected onto it fall within channel complexes that are different from that shown on their other figures. The map of the distribution of channel complexes (their Fig. 20) does not show the location of wells and outcrops. We have redrawn that map and overlaid their data locations (our Fig. 2). Of the many inconsistencies noticed, the most obvious are listed here:

1) Well AB/14-30-92-9 is shown within Channel Complex 4 in Langenberg et al.'s (2002) Figure 13, but is within Channel Complex 3 in both their Figure 14 (section B–B') and on the channel complex map (our Fig. 2).

2) Well AA/4-31-92-9 is shown within Channel Complex 4 in their Figure 13, but would lie within Channel Complex 2 on the channel complex map (our Fig. 2).

3) Channel Complex 4 is shown to intersect the top of outcrops 3-1 and 3-2 in their Figure 14 (section B–B'), but not in their Figure 13. (Outcrops 3-1 and 3-2 were not annotated on Fig. 14. We presume they are the two unmarked outcrop sections adjacent to outcrop 3-3.)

4) The synthetic for the well AB-14-29-92-W4 (their Fig. 17) is annotated to indicate that it penetrates Channel Complex 2, but is located within Channel Complex 3 in their Figure 13.

5) The three wells in the cross-section of their Figure 15 are interpreted differently from the same wells on the structural cross-sections in their Figures 13 and 14. In Figures 13 and 14, the three wells have a ‘Lower Upper McMurray’ unit. This unit is missing in Figure 15 where the lower part of the upper McMurray Formation has been included entirely in Channel Complex 2.

Based on the first three inconsistencies identified above, no wells appear to fall within Channel Complex 4. Channel Complex 4 therefore appears to be defined entirely by only a sliver of section a few metres thick at the top of Outcrop 3 (see Fig. 14 in Langenberg et al., 2002). Even this is not clear because that relationship is not shown in a similar manner in their Figures 13 and 14. Our observations suggest no obvious evidence for the existence of a discrete Channel Complex 4 incising into the top of Outcrop 3 (our Fig. 3). Moreover, if no wells penetrate Channel Complex 4 and only a few metres of it are purported to be exposed in outcrop, then we question how the synthetic was produced for the seismic modeling.

All of this begs the question: how have Langenberg and his colleagues differentiated the four ‘channel complexes’ they claim to recognize? Their entire conceptual model for the Steepbank River area is questionable.

The problem of correlating the McMurray Formation from surface to subsurface is empirically well-known. The current state of high resolution seismic technology shows great promise, and Langenberg et al. (2002) provide evidence for this using actual data from the Clarke Creek lease. It is apparent, however, that their channel complex model from the Steepbank River outcrops and surrounding wells is based on questionable criteria and is likely incorrect. Modeling the seismic response of the McMurray Formation is useful to demonstrate that there is consistent contrast in acoustic impedance to allow the interpretation of high resolution seismic over the oil sands area, and Langenberg and his colleagues have done a commendable job in this respect. In fact, as a methodological initiative, this foray into seismic modeling of McMurray strata is certain to have long-term value. But in our opinion, this study does not convincingly project the existence or the extent of ‘channel complexes’ in the subsurface beyond the exposures evident in outcrop.

**Stratigraphic Framework**

Langenberg et al. (2002) (with reference to Hein et al., 2000) have proposed eliminating the informal, tripartite, lower, middle and upper stratigraphic subdivision of the McMurray Formation in favour of simply an upper and lower McMurray, albeit still informal. This is unacceptable for several reasons. There is little advantage in substituting one informal stratigraphy with a different informal stratigraphy, especially when the tripartite subdivision is engrained in the literature and in general use by the commercial petroleum industry. If Langenberg and his colleagues have done a commendable job in this respect. In fact, as a methodological initiative, this foray into seismic modeling of McMurray strata is certain to have long-term value. But in our opinion, this study does not convincingly project the existence or the extent of ‘channel complexes’ in the subsurface beyond the exposures evident in outcrop.
is no palynological evidence for a break between the traditional middle and upper McMurray (Hein et al., 2000). However, palaeontological evidence is not a criterion for subdivision of lithostratigraphic units (North American Commission on Stratigraphic Nomenclature, 1983).

On the other hand, there is much evidence that there is a differentiation between a ‘middle’ and ‘upper’ McMurray. At the outcrops along the Steepbank River itself, the most noticeable contact is typically the contact between the IHS beds (‘channel complexes’ of Langenberg et al., 2002) and the overlying vertically accreting beds. This is well demonstrated at Outcrop 3 (our Fig. 3). Besides the obvious architectural differences, close examination shows that the sedimentary facies in the upper unit are completely different from the underlying beds, a fact pointed out by Langenberg et al. (2002). The upper unit is characterized in places by the close juxtaposition of facies containing rooted horizons and facies containing marine ichnofossils (e.g. Conichnus, interpreted to result from the behaviour of a sea anemone, and therefore nearly fully marine and intolerant of fluctuating brackish-water conditions). These facies are clearly not the result of a channel abandonment process. This facies association is common in the upper part of the McMurray Formation, but our observations indicate that it is not known from within the middle or lower part of the McMurray Formation at the Steepbank River. We accept that these features are not sufficient by themselves to formally differentiate lithostratigraphic units. However, on an informal basis such features have long been used to differentiate an upper unit within the McMurray Formation, both commercially and academically (Carrigy, 1959; Flach, 1984; Fox, 1988). For

Fig. 1. Photo of Steepbank River, Outcrop 4 (2002), Section 1, taken from the air normal to the outcrop face. Compare this photo to that of Langenberg et al. (2002, their Fig. 12). Langenberg et al. claim that Channel Complex 3 is separated from Channel Complex 2 by an inclined discordant surface, interpreted as an episode of cut and fill. In reality, it can be seen here that the contact is more or less horizontal (and parallel to the upper contact of Channel Complex 3 with the upper McMurray). There is no indication of a cut and fill incision. To the south (left in the photo), the contact is covered with scree, but nowhere can it be seen to incise down discordantly into the underlying strata. The IHS beds overlying and underlying the contact do dip in apparently opposing directions and are discordant in that regard, but the contact itself is generally horizontal on this outcrop face.
example, at the nearby Syncrude Mine, an ‘upper’ McMurray member is well documented and an integral part of their commercial stratigraphic scheme (O’Donnell and Jodrey, 1985). Langenberg et al. (2002) acknowledge that three informal members are identified in many areas and in many commercial developments, but state that “…regional isochronity of the members cannot be demonstrated” (p. 180). We reiterate that isochronity is not a criterion for differentiating lithostratigraphic units. Indeed, the North American Stratigraphic Code specifically addresses the “independence (of lithostratigraphic units) from time concepts” under article 22e (North American Commission on Stratigraphic Nomenclature, 1983, p. 856). Langenberg et al. (2002) are guilty of confusing lithostratigraphic units with chronostratigraphic units.

Curiously, in each of their cross-sections and stratigraphic descriptions, Langenberg et al. (2002) have differentiated a distinct upper unit of their ‘upper McMurray’ member. In some cases the cross-sections in Langenberg et al. (2002; e.g. see their Figs. 13, 14) even imply a four-fold subdivision wherein their ‘upper’ McMurray is subdivided into an upper upper McMurray, lower upper McMurray and an uncaptioned middle unit, presumably ‘middle upper McMurray’.

Recent work by Ranger and Pemberton (1997), Caplin and Ranger (2001), and various unpublished submissions to the Alberta Energy and Utilities Board (EUB Chard Leismer Gas - Bitumen Hearings) have demonstrated that there exist distinct correlateable coarsening- and sandier-upward parasequences in the upper part of the McMurray Formation. These are floored by transgressive surfaces of erosion/flooding surfaces and are preserved over much of the Athabasca area. These units are mappable both from core and wireline logs, and have lithologically distinct facies associations. That may not be sufficient to designate them as formal lithostratigraphic units; we suggest however, that these units probably meet the criteria for member status as allostratigraphic units, specifically allomembers, although a formal nomenclature has yet to be proposed. There is little doubt, therefore, that due to the actively evolving stratigraphic studies of the McMurray Formation, any change to (and especially a contraction of) the informal stratigraphic nomenclature at this time is unwarranted and unwise. Langenberg and his colleagues are free to use their own stratigraphy where none formally exists. However, we suggest that rather than revising traditional informal nomenclature, they use a different set of unique nomenclature; for example, McMurray A and B. The constant reference to the upper McMurray when referring to the traditionally defined middle McMurray is confusing, or at best severely distracting.

OTHER INCONSISTENCIES

In their conclusions, Langenberg et al. (2002) state that bitumen grade may be predicted from seismic data. This conclusion has not been demonstrated. Perhaps bitumen-prone reservoir facies may be predicted, but certainly not bitumen grade. For example, basal- or top-water zones and poorly saturated zones, which exist at the Steepbank River area and/or Mobil Clarke Creek Lease, have not been predicted from seismic data.

In the section “Relationship Between Channel Complexes”, referring to Channel Complex 3, Langenberg et al. (2002, p. 195) state that: “…an interbedded sandstone-shale infill is suggested by the presence of high-amplitude reflectors. These reflectors are drape folded and conform generally to the basal erosion surface of the channel complex.” This statement defies logic because the seismic section is not a geological section, but a model derived from it. One can make conclusions about a seismic model generated from the stratigraphic data; however, conclusions about the stratigraphy cannot be made from the seismic model, and to state otherwise appears to be an example of circular reasoning.

The presence of the fault shown on the east–west cross-sections (their Figs. 13, 16, 18) is tenuous. Although Langenberg et al. (2002) refer to unpublished evidence suggesting the presence of a “…lineament in the area” (p. 188), there is no outcrop evidence for this feature. The cross-section in Figure 13 is misleading in this regard. Figure 13 is drafted to show wells in close proximity to Outcrop 7 that seem to indicate an abrupt structural offset of about 15 metres. But whereas well AE/1-30-92-9 is located on the cross-section about 100 metres from Outcrop 7 on the other side of the fault, in reality it is about 500 metres...
away (our Fig. 2). Another well (AB/14-29-92-9) is actually over 700 metres away from Outcrop 7, yet is located on the cross-section less than 350 metres away. This misrepresentation exaggerates the appearance of structural offsets shown on the cross-section, which otherwise shows considerable structural undulation.

**OUR CONCLUSIONS**

Langenberg et al. (2002) present no credible evidence for their differentiation of ‘channel complexes’ in the Steepbank River area. Their main criteria appear to be paleocurrent directions and down-cutting stratigraphic relationships, yet their measured paleocurrent directions are all similar enough that they are consistent with a single channel complex, given the variation that would be expected in a meandering channel system. Furthermore, they show no evidence of a down-cutting incision relationship between ‘channel complexes’ from either core or outcrop. Their correlation of channel complexes from outcrop to subsurface does not appear to be based on hard evidence.

There are so many errors — in fact, inconsistencies — in interpretation, and unsubstantiated correlations, that the conceptual model suggested by Langenberg and his colleagues for the McMurray Formation in the area of the Steepbank River outcrops cannot be supported. We have little confidence in the interpretations presented in their study. In our opinion it is doubtful that the presence and distribution of ‘channel complexes’, as described in Langenberg et al. (2002), actually exists.

This conclusion also throws doubt on the interpretation of the data from the Clarke Creek area. The interpreted seismic lines presented in Langenberg et al. (2002, their Figs. 24, 25, 26) show deep incision, up to 55 metres thick, with complete removal of one ‘channel complex’ by another. Such features have not been observed in outcrop on the Steepbank River, and are not obvious in the single partial seismic line from the Clarke Creek area (their Fig. 26).

The revised stratigraphy presented by Langenberg et al. (2002), wherein the informal middle and upper McMurray members are merged into one unit, is untenable. Over much of the Athabasca oil sands area including the Steepbank River, the

Fig. 3. Photo of Steepbank River, Outcrop 3. The laterally accreting beds of the informal middle McMurray member are overlain by vertically accreting beds of the informal upper McMurray member. Besides the obvious architectural contrast in bedding style, there is a distinct change in facies and facies association. Moreover, allostratigraphic bounding discontinuities have been recognized and mapped regionally from the upper McMurray member over a wide area in the subsurface. Langenberg et al. (2002) propose lumping these informal and widely-used units into a single upper McMurray member, claiming it is not possible for them to biostratigraphically distinguish between the middle and upper McMurray. However, biostratigraphic and chronostratigraphic criteria have no place in a lithostratigraphic scheme.
site of their own work, a distinct upper McMurray unit can be observed. It is assuredly a complex unit, as is typical of the McMurray Formation, but it contains unique facies associations and allostratigraphic features that can be mapped over wide areas from both core and wireline logs.

The McMurray Formation is currently undergoing a surge in stratigraphic scrutiny prompted in part by an acceleration in commercial development as well as legal issues regarding, for example, the gas over bitumen debate. If anything, we predict that the McMurray Formation is destined to be formally subdivided into even finer stratigraphic units than at present. Consequently, it appears premature (as well as demonstrably incorrect) to eliminate stratigraphic units from the current traditional, if informal, stratigraphic scheme.

The study by Langenberg et al. (2002) is a good attempt to develop the application and interpretation of seismic methods for McMurray Formation strata. However, it does little to further the knowledge of McMurray stratigraphy and sedimentology, and indeed, in our opinion, sets it back with misleading and indefensible interpretations and ill-conceived ideas for the stratigraphic nomenclature.

REFERENCES


