U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Kinematic and subsidence modeling of the north-central Brooks Range and North Slope of Alaska

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Open File Report 95-823

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Explanation of Sheet 1--
"Geologic map of parts of the Killik River, Howard Pass, Ikpikpuk River, and Lookout Ridge quadrangles, Alaska"

This geologic map is based on surface geology compiled from published and unpublished geologic maps dated 1948-1994, including field observations made by a USGS field party in 1993. In addition, this map includes subsurface structures imaged on USGS seismic lines and reported by Tetra-Tech Inc. (1982). All references are listed on Sheet 1.

In addition to geologic relations, the map shows locations of 1) seismic line 37, used in the seismic interpretation displayed on Sheet 2 of this report; 2) locations of two USGS-drilled wells, Lisburne #1 and Oumalik #1, both used for stratigraphic and structural calibration of seismic line 37.

The geologic map encompasses most of the foreland fold- and thrust-belt, extending northward from folded and imbricated Upper Devonian sedimentary rocks, to the northernmost mappable anticline at the Oumalik #1 well. This anticline involves all of the Cretaceous stratigraphic section preserved at this locality.

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Explanation of Sheet 2--
"Seismic interpretation of Line 37 and forward kinematic model of the fold- and thrust-belt"

Seismic interpretation:
The seismic interpretation is based on the surface geology (shown on Sheet 1), subsurface seismic geometries from line 37 and adjacent lines, and well logs available through the USGS.

At the southern end of the seismic interpretation, a north-dipping hanging wall cut-off of Kanayut conglomerate forms the topographic front of the Brooks Range. In detail, this wedge is itself made up of multiple thrust slices of Hunt Fork shale and Kanayut conglomerate, but it is shown schematically here as a thick Hunt Fork-Kanayut structural composite.

Along the surface to the north of the Hunt Fork-Kanayut wedge, we observe the Picnic Creek allochthon, preserved at the locally highest structural level in a regional synform. We presume that this allochthon (PMp and TRPp on the section) was carried passively on the back of the Hunt Fork-Kanayut units during their emplacement.

Farther north, the seismic interpretation passes through the area of the Lisburne #1 well, which penetrates five fault repetitions of Lisburne Group limestone, simplified at this scale to three fault repetitions. We interpret this zone as an antiformal stack or duplex formed at the leading edge of the deforming wedge. The Lisburne Group produces prominent reflections within in the antiformal stack, and these same reflections dip uniformly southward beneath the Hunt Fork-Kanayut wedge. We suspect that the strongly reflective horizon at 4.5 seconds beneath shot point 970 is also Lisburne Group carbonate, here near its autochthonous position.

To the north of the Lisburne well is a zone of complex, melange-style deformation, represented on this section by folded thrust faults immediately north of the well. This zone may represent the tip of a triangle zone, beneath a regional backthrust. However, we have shown it here as a series of forward-propagating thrusts for the purpose of kinematic modeling with Thrustpack.

North of the melange zone, the foreland basin sedimentary fill is deformed in gentle folds and offset by growth faults, which show increasing displacement in the down-dip direction. Upper Albian to Cenomanian sediments fill piggy-back basins and probably date the Lisburne duplex and additional anticlines to the north.

Kinematic model:
The kinematic model was performed with Thrustpack software, developed by the Institut Français du Petrole, and used courtesy of IFP, Chevron, Instituto Mexicano del Petroleo, and INTEVEP. The model begins with a palinspastic restoration of the seismic interpretation ("1. Initial undeformed state") and proceeds forward with deformation until something resembling the present-day geometry is achieved ("4. Final state"). The timing of successive stages of deformation are estimated largely from sedimentological evidence-- primarily from the ages of orogenic clastics, foreland basin subsidence events, and piggy-back basins. The sequence and style of deformation are limited somewhat by the forward modeling software-- Thrustpack does not allow backthrusts or out-of-sequence thrusts, so our model is a simple forward-propagating thrust model.

The first episode of deformation in this part of the fold- and thrust-belt involves the emplacement of the Devonian allochthons (Hunt Fork-Kanayut structural wedge) onto the continental platform. This overthrusting episode is thought to be responsible for the major tectonic subsidence episode that affected the foreland in Barremian to Aptian time. This began deep water flysch sedimentation in the foreland.

The second phase of deformation is the thin-skinned thrusting that formed the antiformal stack at the Lisburne well. We think this structure is Late Albian to Cenomanian in age, because this is the age of the sediments

deposited with multiple unconformities in piggyback basins to the north of the antiform.

In the final state of deformation, a considerable amount of sedimentary cover has been stripped off to achieve the present-day erosion level. Based on seismic stratigraphy near Prudhoe Bay, as well as apatite fission track ages, we suspect that this episode of regional erosion took place in mid-Eocene time.

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Explanation of Sheet 3--
"Tectonic subsidence modeling"

Sheet 3 shows the tectonic subsidence modeling that we performed in the foreland basin, to constrain the timing of thrust loading and other geodynamical events. We analyzed the basin subsidence history by backstripping five government-drilled wells (Seabee #1, Inigok #1, North Inigok #1, East Teshekpuk #1, and Cape Halkett #1), shown on map and cross-section at the far left of Sheet 3. The map and seismic section also show the Barrow Arch along the north rim of the foreland basin, and the Brooks Range on its southern edge.

By analyzing changes in sedimentary thickness and paleo-water depth through time, we can observe both the thermal effects of uplift along the Barrow Arch, as well as the flexural effects of tectonic loading in the Brooks Range orogen.

The tectonic subsidence history at each well is represented by a graph on the righthand side of Sheet 3. For each well, three curves are shown: the green curve is the total subsidence curve, which is equal to the decompacted sedimentary thickness plus water depth, through time; the blue curve shows our estimates of paleo-water depth through time, taken from seismic clinoforms, and lithofacies; and the red curve shows the resulting tectonic subsidence curve after backstripping, that is after the weight of the sedimentary load has been removed. This red curve is thought to represent the tectonic subsidence history of the foreland basin.

The red curves are enlarged to show detail in the upper righthand corner of Sheet 3. Here we see the first-order geodynamical effects on the North Slope foreland basin: 1) Late Neocomian (Hauterivian) uplift concentrated along the Barrow Arch, represented by the regional unconformity known as the "lower Cretaceous unconformity" or the "pebble shale unconformity," and 2) large-magnitude subsidence of the North Slope during Barremian to Aptian time, presumably during the greatest overthrusting episode in the central part of Brooks Range Orogen.