Chapter FS (Field Studies, 1995-1997)

USGS ARCTIC NATIONAL WILDLIFE REFUGE FIELD SUMMARY, 1995-1997

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in The Oil and Gas Resource Potential of the 1002 Area, Arctic National Wildlife Refuge, Alaska, by ANWR Assessment Team, U.S. Geological Survey Open-File Report 98-34.

1999

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ABSTRACT

Personnel from the USGS Energy Team in the course of assessing the oil and gas potential of the Arctic National Wildlife Refuge (ANWR) examined over 120 localities in and around the 1002 Area of ANWR. The field investigations included measuring stratigraphic sections, determining geologic structure and structural evolution, and sampling for numerous laboratory analyses, including vitrinite reflectance, sandstone petrography, shale diagenesis and geochemistry, oil and source rock geochemistry, porosity evolution of sandstones, apatite-fission-track analysis, palynology and other biostratigraphy, and fluid inclusion studies. Several hundred samples were collected, examined, and analyzed from the more than 120 localities. This data set from the field was used in conjunction with other data sets to develop the geological framework prior to assessing the oil and gas potential of ANWR.

INTRODUCTION

The Energy Team of the USGS conducted limited field work in and around the 1002 area of the Arctic National Wildlife Refuge in the summers of 1995, 1996, and 1997. The USGS ANWR project chief is Kenneth J. Bird. The 1995 field session, led by D.L. Gautier, was an introduction to the geology of the 1002 area to most of the field personnel. The 1996 session was split into two; the first part, led by R. C. Burruss, focused on geochemical studies, and the second part, led by C. J. Schenk and D.H. Houseknecht, was mainly concerned with sedimentologic and stratigraphic studies. The 1997 session was also split in two parts; the first, led by R. C. Burruss, focused on structural and geochemical studies, and the second, led by C. J. Schenk and D.W. Houseknecht, again focused on sedimentologic and stratigraphic studies. The following is a brief summary of most of the activities conducted during our short field sessions in and around the ANWR 1002 area. A compilation of USGS field work completed prior to 1995 is included in a separate chapter (Appendix CM).

Permission to conduct geologic investigations in ANWR, including the use of helicopters, was granted each year to the USGS through a “special use permit” issued by the U.S. Fish and Wildlife Service, which has the operational jurisdiction for ANWR.

All samples cited here with the designation "DH" or "RCB" are stored at the USGS in Reston, Virginia, and all samples with designations of "FC" or "DLG" are stored in Menlo Park, California. All GPS coordinates in this document are presented as degrees, minutes, decimal-seconds (as recorded from the helicopter), calculated degrees-minutes-seconds, and as calculated decimal-degrees. All field localities with GPS coordinates appear on Plate FSP1.

FIELD WORK SUMMARY - AUGUST 2-10, 1995

The purpose of this first field session was to introduce several project personnel to as much of the sedimentary section and styles of deformation as possible in the short time we would spend in the field. The field time in 1995 was spent examining and sampling many localities rather than measuring stratigraphic sections.

Field Personnel- August 2-10, 1995

Frances Cole (USGS, Menlo Park)
Donald L. Gautier (USGS, Denver)
David W. Houseknecht (USGS, Reston)
Timothy R. Klett (USGS, Denver)
C. Gil Mull (Alaska Survey, Fairbanks)
Christopher J. Schenk (USGS, Denver)
Kenneth I. Takahashi (USGS, Denver)
Jamie Toro (Stanford University)

AUGUST 2, 1995; Wednesday

All field personnel traveled to Fairbanks, Alaska. We spent the night at the Golden North Motel.

AUGUST 3; Thursday

All personnel waited in Fairbanks for North Slope weather to clear sufficiently to allow travel to Kavik Camp. The weather forced us to remain in Fairbanks, and we went back to the Golden North Motel. We were originally scheduled on a charter flight from Fairbanks to Kavik, and we decided to change to a commercial flight. The helicopter and pilot had to

overnight in Chandalar due to the weather. As always, movement on the North Slope is completely dependent upon the weather.

AUGUST 4; Friday

All field personnel traveled from Fairbanks to Deadhorse via commercial airline, and then we traveled in two groups to Kavik Camp via a Cessna 207 flown by 40-Mile Air, a 45-minute ride from Deadhorse. We arrived in the late afternoon in a light rain and fed the hordes of mosquitoes.

Kavik Camp, situated on the Kavik River about 70 miles southeast of Deadhorse, was an excellent base of operations for helicopter-supported investigations of ANWR and the central North Slope. Western ANWR 1002 is easily reached from Kavik, whereas eastern ANWR 1002 requires a fuel cache or refueling in Kaktovik for helicopter operations. The facility at Kavik is mainly a staging camp for hunting expeditions to the Brooks Range and vicinity (Figure FS1).

Logistical Support- Deadhorse and Kavik

Kavik Camp Manager: Sami Superdock
40-Mile Air pilot: Rick
Air Logistics helicopter (N130AL) pilot: Gordon Ortelli

We arrived at Kavik Camp relatively late in the afternoon, but we quickly arranged for several of the field personnel to visit localities close to camp, as we were all champing at the bit to get going, having already lost a day. A selection of panoramas and still photographs taken during this week are located elsewhere in this document (Chap. IG).

Kemik/Kingak west of the Kavik River (Gautier, Cole, Toro)

Locality 95-1; GPS- N69,23.81; W146,25.08 (N69,23,49; W146,25,05)
GPS decimal degrees equivalent- N69.3969; W146.4181
Sample Numbers: 95FC-01A to 95FC-01D

We examined the exposures of the Kingak Shale and Kemik Sandstone just west of the Kavik River. The Kemik Sandstone at this locality is a thin cap on a low ridge west of the Kavik River. We sampled for apatite-fission-track analysis (AFTA), vitrinite, and concretions for early diagenesis.

Hue Shale on Kavik River (Gautier, Cole, Toro)

Locality 95-2; GPS- N69,27.99; W146,34.84 (N69,27,59; W146,34,50)
GPS decimal degrees equivalent- N69.4664; W146.5801
Sample Numbers: 95FC-02A, 95FC-02B

We examined the Hue Shale and its interesting bentonites along the limb of a steep fold along the Kavik River. Samples were taken for vitrinite and clay maturity.

AUGUST 5; Saturday

The plan today was complicated by the need to ferry people to various places. First, Houseknecht, Schenk, and Takahashi were dropped along the Canning River to examine the Tertiary outcrops, then Cole and Toro were dropped along the Canning several miles to the south, where they examined the Kemik and Hue Shale. Cole and Toro then walked north to "Craig Rock", where Houseknecht and Schenk were flown to join them. Meanwhile, Takahashi was flown north to join Gautier, Klett, and Mull as they examined outcrops along the Marsh Creek Anticline. The helicopter then stayed with Gautier and others, and they returned to Kavik first. All the rest were picked up later. The day began with light rain, which only got worse as the hours went by.

Canning River Paleocene clinoforms (Houseknecht, Schenk, Takahashi)

Locality 95-3; GPS-N69,34.89; W146,18.52 (N69,34,53; W146,18,31)
GPS decimal degrees equivalent- N69.5814; W146.3086
Sample Numbers: DH95-1P, DH95-1A, DH95-2 to DH95-4

Low cloud ceiling, limited visibility and snow limited the options today for helicopter travel. We traveled to the Canning River where Canning Formation clinoforms are well-exposed in an east-facing river bluff. These deposits are commonly observed on seismic, and this exposure afforded an opportunity to better interpret the seismic data. We observed thin-bedded turbidites, amalgamated sandstones, large-scale low angle truncations, and large-scale slump structures in fine-grained sediments (Figure FS2).

Canning River Kemik Sandstone and Hue Shale (Cole, Toro)

Locality 95-4; GPS- N69,31.78; W146,18.17 (N69,31,47; W146,18,10)
GPS decimal degrees equivalent- N69.5297; W146.3028
Sample Numbers: 95FC-03A to 95FC-03E

We flew south along the Canning River and examined the Kemik and Hue at a locality known as the "Emerald Isle" by ARCO geologists who trenched and described this section. We sampled for AFTA, concretions for early diagenesis, sandstone petrography, and vitrinite.

"Craig Rock" section (Houseknecht, Schenk, Cole, Toro)

Locality 95-5; GPS- N69,32.51; W146,17.72 (N69,32,31; W146,17,43)
GPS decimal degrees equivalent- N69.5419; W146.2953
Sample Numbers: DH95-4A, DH95-4B; 95FC04A, 95FC04B

We were flown south to meet up with Cole and Toro to examine an outcrop labeled Canning Formation on the map, but an interpretation of the depositional environments indicated that this should be Sagavanirktok Formation. In 1997 we called this the "Craig Rock" section after the pilot. Samples were taken for petrography and for AFTA. In very heavy rain we tried to hike north downriver to another outcrop, but we were forced to hunker down in the gathering gloom and wait until the early evening for the helicopter to arrive. We were all amazed to be picked up, as the weather was terrible.

Marsh Creek Anticline (Gautier, Klett, Takahashi, Mull)

Locality 95-6; GPS- N69,56.82; W144,39.95 (N69,56,49; W144,39,57)
GPS decimal degrees equivalent- N69.9469; W144.6658
Sample Numbers: 95-DLG-1A, 95-DLG-1B

In the rain we visited Carter Creek on the Marsh Creek Anticline and sampled an unconsolidated sand with ironstone concretions, and we sampled sandstones for petrography. We then moved north to a bluff along the Katakturuk River.

Bluff along Katakturuk River (Gautier, Klett, Takahashi, Mull)

Locality 95-7; GPS- N69,52.26; W145,10.76 (N69,52,16; W145,10,46)
GPS decimal degrees equivalent- N69.8711; W145.1794
Sample: 95-DLG-2A, 95-DLG-2B, 95-DLG-2C

We stopped at a bluff on the east bank of Katakturuk Creek, which was a Tertiary fluvial conglomerate and sandstone. The conglomeratic sandstone had something in it that Mull called "Tasmanites", and this stuff may explain the anomalous vitrinite values from this locality. The oil-stained sandstone is sample 95-DLG-2A, and sample 95-DLG-2B is from a carbonaceous layer in the sandstone that was not "Tasmanites". Sample 95-DLG-2C was sandstone taken for AFTA and petrography. We then went to another locality on the Katakturuk River.

West Bank of Katakturuk River (Gautier, Klett, Takahashi, Mull)

Locality 95-8; GPS- N69,51.70; N145,16.72 (N69,51,42; W145,16,43)
GPS decimal degrees equivalent- N69.8617; W145.2786
Samples: 95-DLG-3A, 95-DLG-3B

We flew to a locality on the west bank of the Katakturuk River where there is an outcrop of marine shale with large concretions. The concretions were very interesting. Sample 95-DLG-3A is from the shale below the concretion, and sample 95-DLG-3B is from the concretion.

We all gathered at Kavik Camp that evening listening to the heavy rain drum on the roof of the mess tent.

AUGUST 6; Sunday

The plan today was to get Houseknecht, Schenk, and Takahashi to the East Fork of Marsh Creek. Toro and Cole were dropped off to examine exposures along Curve Creek to the south, and Gautier, Klett, and Mull were to spend the day in the area of the Niguanak High and beyond.

East Fork of Marsh Creek (Houseknecht, Schenk, Takahashi)

Locality 95-9; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489

Sample Numbers: DH95-5 to DH95-20

We traveled to the East Fork of Marsh Creek on the north side of the Sadlerochit Mountains where a significant Ellesmerian sedimentary section is exposed. We examined the Lisburne Group, Kavik Shale, Ledge Sandstone, the Lower Cretaceous unconformity (LCU), Kingak Shale, and the duplexes in the Kemik Sandstone. There is significant erosion associated with the LCU in this area. The Ledge Sandstone contains three major sedimentary sequences, and is unconformably overlain by the Kemik (Figure FS3). The Ledge Sandstone in this area is shallow marine to tidal in origin.

We were picked up after 6:00 pm by a helicopter pilot from Alyeska flying a Messerschmidt, who said that there had been a problem with our helicopter. We arrived at Kavik Camp to find that the others had still not returned. The Alyeska pilot then went and picked up Cole and Toro at Curve Creek.

Curve Creek (Cole, Toro)

Locality 95-10; GPS- N69,18.03; W145,44.61 (N69,18,02; W145,44,37)
GPS decimal degrees equivalent- N69.3006; W145.7436
Sample Numbers: 95FC-05 to 95FC-12

We flew south to Curve Creek and examined the Neurukpuk Formation, the Kekiktuk Formation, the Lisburne Group, and the Sadlerochit Group. We sampled extensively for vitrinite, AFTA, and petrography.

Trip to Niguanak and beyond (Gautier, Mull, Klett)

After waiting for the others to be ferried, we began the day by flying east from Kavik to Kaktovik, as we had to refuel in order to make it further east to the Niguanak area. We became bogged down in the coastal fog near Kaktovik, and we were running out of fuel. We set down on the beach among the jetsam, and radioed for someone to bring over a barrel of fuel in a boat from Kaktovik, which to our amazement actually happened. An ominous beginning. We then hopped over the lagoon to Kaktovik and refueled at the USFWS facility. We then flew east to the outcrop area on the crest of the Niguanak High.

Tributary to the Niguanak River (Gautier, Klett, Mull)

Locality 95-11; GPS- N69,53.04; W143;07.41 (N69,53,02; W143,07,25)
GPS decimal degrees equivalent- N69.8839; W143.1236
Sample Numbers: 95-DLG-4A, 95-DLG-4B, 95-DLG-4C

We visited outcrops on the tributaries to Niguanak River, where our primary duty appeared to be to feed the hordes of mosquitoes. Sample 95-DLG-4A was from marine Hue Shale, and 95-DLG-4B was a Hue bentonite; we sampled by trenching in stream bottom. Sample 95-DLG-4C was Hue Shale. We then flew to the Kingak outcrop on the Niguanak structure.

Kingak Shale on the Niguanak (Gautier, Mull, Klett)

Locality 95-12; GPS- N69,53.91; W143,03.11 (N69,53,55; W143,03,07)
GPS decimal degrees equivalent- N69.8986; W143.0519
Sample Numbers: 95-DLG-5A and 95-DLG-5B

We stopped along an easterly tributary to the Niguanak River where there was an outcrop of Kingak Shale. We sampled the Kingak Shale in trenches dug one cubit into the cut-bank. Mull said he collected ammonites and rudistids(?) from this outcrop that he says is Jurassic in age. We then flew to an outcrop with oil-bearing sandstones.

Oil-bearing sandstone outcrop (Gautier, Mull, Klett)

Locality 95-13; GPS- N69,55.07; W143,22.66 (N69,55,04; W143,22,40)
GPS decimal degrees equivalent- N69.3850; W143.3778
Sample Numbers: 95-DLG-6A, 95-DLG-6B

At this outcrop we sampled the oil-saturated sandstone (sample 95-DLG-6A) and a concretion (sample 95-DLG-6B).

After this locality, we began the return to Kavik by flying west back to Kaktovik, where we again refueled at the USFWS facility. We then headed west along the coast, which was badly fogged in, forcing us to head southwest and fly low over the coastal plain. At the valley of the Katakturuk River, we again were out of fuel, which meant we had to set down on the tundra and activate the emergency beacon. We spent the night in the helicopter, sending signals from both the emergency beacon and

repeated distress calls. Amazingly, in the morning, a pilot flying a commercial Lufthansa flight on a polar route picked up the distress call, and said he would contact flight operations in Deadhorse, which he did. Deadhorse flight operations sent someone out to us in a helicopter with a barrel of fuel, which allowed us to return to Kavik Camp in the early afternoon.

AUGUST 7; Monday

The helicopter had not returned by the morning, which caused some loss of stomach lining, so by mid-morning the bunch of us at Kavik decided we must get something done while the weather was good. Travel on the North Slope is difficult without helicopter support, but we decided to hike south and examine an outcrop of the Sagavanirktok Formation several miles from camp. We brought the small raft from camp, as the Kavik River would have to be crossed.

Sagavanirktok Formation on the Kavik River (Houseknecht, Schenk, Toro, Cole, Takahashi)

Locality 95-14; GPS- not recorded
Sample Numbers: DH95-21 to DH95-23; 95FC-13A to 95FC-13C

The Sagavanirktok Formation at this locality represents massive, coarse grained, amalgamated fluvial channel sandstones typical of seismic topset facies (Figure FS4). The sandstones are variably cemented with calcite, and we found no evidence of oil staining that has been reported from this locality. After sampling the sandstones and a coal up-section from the sandstones, we piled onto the raft and tried to negotiate the shallow water of the Kavik River back to camp. The helicopter had arrived before we returned; all were safe.

In the late afternoon, we resumed flying with our own helicopter, which now had more fuel put into it for each flight. No one had ever heard of someone running out of fuel twice in the same day.

With the good weather, we decide to examine some exposures along the Canning River. Gautier and Takahashi went to the Kemik duplexes along the Canning, and then Houseknecht and Schenk went to “Shublik Island”, where we were joined by Gautier and Takahashi.

Kemik duplexes along Canning River (Gautier, Takahashi)

Locality 95-15; GPS- N69,29.97; W146,18.56 (N69,29,58; W146,18,34)
GPS decimal degrees equivalent- N69.4994; W146.3094
Sample Numbers: 95-DLG-7A, 95-DLG-7B

We visited the outcrops of Kemik Sandstone along Canning River where the Kemik duplexes are exposed. Sample 95-DLG-7A was from the Kemik Sandstone, and 95-DLG-7B was from the Kingak Shale beneath the Kemik from northernmost Kemik outcrop. We then flew south to the exposure known as "Shublik Island", where the Sadlerochit Group is exposed. The Sadlerochit Group is structurally complex in this area.

"Shublik Island" on the Canning River (Gautier, Houseknecht, Schenk, Takahashi)

Locality 95-16; GPS- N69,21.87; W146,01.78 (N69,21,52; W146,01,47)
GPS decimal degrees equivalent- N69.3644; W146.0297
Sample Numbers: 95-DLG-8A, 95-DLG-8B

The Sadlerochit Group is deformed and exhibits structurally produced cleavage, and is loaded with slickensides. Sample 95-DLG-8A is a slab of Sadlerochit sandstone from an outcrop that was deformed, and 95-DLG-8B was carbonaceous shale from the Sadlerochit Group. From here we all ferried back to Kavik for the night.

AUGUST 8; Tuesday

This was one of the most perfect weather days seen on the North Slope. As Gil Mull says, when the weather is nice on the North Slope, it can be really nice. Houseknecht and Schenk went to Fire Creek Canyon to examine the Ellesmerian section, and Gautier, Klett, Cole, and Takahashi traveled to Hue Creek to examine and sample the Hue Shale section. Mull and Toro traveled south to examine structures in the Brooks Range.

Fire Creek Canyon (Houseknecht, Schenk)

Locality 95-17; start of traverse-GPS- N69,31.93; W145,12.67, (N69,31,56; W145,12,40), GPS decimal degrees equivalent N69.5322;

W145.2111; end of traverse-N69,32.33; W145,11.60 (N69,32,20; W145,11,36), GPS decimal degrees equivalent- N69.5389; W145.1933
Sample Numbers: DH95-24 to DH95-40

Fire Creek Canyon on the east end of Ignek Valley contains a nearly complete exposure of the Ellesmerian sedimentary section. We flew to the Fire Creek Canyon, dropping Takahashi on top of Ignek Mesa en route to shoot a photo-panorama (Chap. IG). We first examined the Lisburne Group and the Kavik Shale. We then examined the Ledge Sandstone, which was composed of three sequences, each of which contains shallow marine and tidal deposits, including a possible tidal delta complex. The Ledge Sandstone is overlain by the Fire Creek Siltstone, which was composed of many parasequences of shallow marine sandstones and mudstones rather than siltstone (Figure FS5). The upper sequence of the Fire Creek was composed of tidal deposits, which were abruptly overlain by a thin transgressive lag and the black calcareous mudstones of the Shublik Formation. The Shublik Formation seemed anomalously thick, was spectacularly exposed, and appeared to contain rocks deposited in environments ranging from turbidites to tidal deposits. The Shublik Formation was overlain by the Karen Creek Sandstone, which was a possible fluvial channel sandstone. The Karen Creek (Sag River) was overlain by black mudstones of the Kingak Shale. This section is one of the best Ellesmerian sections on the North Slope.

Panorama photographs from Ignek Mesa (Takahashi)

Locality 95-18; GPS- N69,33.54; W145,18.35 (N69,33,32; W145,18,21)
GPS decimal degrees equivalent- N69.5589; W145.3058
Sample Numbers: none

After dropping us at Fire Creek Canyon, the pilot went back and brought the group to Hue Creek, then he picked up Takahashi from the top of Ignek Mesa and brought him to Hue Creek. We were then taken to the "Horseshoe" section.

Kemik Sandstone at "Horseshoe" Section (Houseknecht, Schenk)

Locality 95-19; GPS- N69,33.39; W145,27.46, (N69,33,23; W145,27,28)
GPS decimal degrees equivalent- N69.5564; W145.4578
Sample Numbers: DH95-41 (vitrinite)

We left Fire Creek and traveled west to a large exposed syncline ("horseshoe") in the central part of the Ignek Valley which contains the Kemik Sandstone. This is the type section of the Kemik Sandstone as designated by Mull in 1987. The Kemik at this locality is comprised of a parasequence set, each parasequence contains hummocky strata to bioturbated sandstone. The obvious orange-red bands within the Kemik may be useful for correlation. This outcrop had previously been drilled for porosity and permeability or paleomag plugs by unknown persons. We hiked west over to "Bear Ridge" and collected a pebble shale sample for vitrinite. We were then flown to Hue Creek to join the festivities already in progress.

Hue Creek (Houseknecht, Schenk, Cole, Gautier, Klett, Takahashi)

Locality 95-20; GPS- N69,34.17; W144,48.73 (N69,34,10; W145,48,44)
GPS decimal degrees equivalent- N69.5694; W145.8122
Sample Numbers: DH95-42 to DH95-44; 95FC-14 to 95FC-24

We met up with the other group to examine the classic source rock locality and stratigraphy at Hue Creek in the Ignek Valley. The section began with a structural sliver of the Shublik and the Kingak, which was followed by the LCU, which is overlain by a thin Kemik Sandstone containing a 3-foot thick chert-pebble conglomerate. The Kemik was overlain by a thick section of the Hue Shale, which is postulated to be one of the most important source rocks in the 1002 area. The Hue Shale is overlain by a thick section of Canning Formation consisting of mudstones and classic thin-bedded turbidites. All of these deposits represent bottomset to clinoform deposits on seismic data. We sampled extensively for vitrinite, vein fillings, inorganic geochemistry, AFTA, and petrography (Figure FS6).

Finally, we all gathered in the central part of the Ignek Valley at the head of Katakturuk Canyon to examine the Kemik Sandstone before returning to Kavik Camp. Kavik Camp was refueled late in the evening by an outfit flying a Curtiss Commando, or a C46, a truly amazing sight.

AUGUST 9, Wednesday

Today Cole and Toro traveled to both the Canning and Kavik Rivers, where they sampled the sections. Houseknecht and Schenk traveled to several key

localities with Gil Mull, who explained the details of the stratigraphy and structure. We had one-half day to examine all of these localities, as we had to return to Deadhorse that afternoon.

Sagavanirktok Formation on Canning River (Cole, Toro)

Locality 95-21; GPS- not recorded
Sample Numbers: 95FC-25 to 95FC-27

We examined the outcrop of the Sagavanirktok Formation in the Canning River at the northwest end of the Sadlerochit Mountains. We sampled for vitrinite and AFTA.

Sampling stops along Kavik River (Cole, Toro)

Locality 95-22; GPS- N69,26.01; W146,41.48 (N69,26,01; W146,41,29)
GPS decimal degrees equivalent- N69.4336; W146.6914
Sample Number: 95FC-28

We sampled mudstones for vitrinite.

Locality 95-23; GPS- N69,37.94; W146,53.17, (N69,37,56; W146,53,10)
GPS decimal degrees equivalent- N69.6322; W146.8861
Sample Number: 95FC-29

We sampled sandstones of the Kemik Sandstone (?) for AFTA.

Locality 95-24; GPS- N69,36.34; W146,41.48 (N69,36,20; W146,41,29)
GPS decimal degrees equivalent- N69.6056; W146.6914
Sample Number: 95FC-30

We sampled Sagavanirktok Formation mudstones for vitrinite.

Tributary to Katakturuk Creek (Houseknecht, Schenk, Mull)

Locality 95-25; GPS- N69,39.71; W145,18.01 (N69,39,43; W145,18,01)
GPS decimal degrees equivalent- N69.6619; W145.3003
Sample Numbers: DH95-45 to DH95-48

We stopped at an exposure on a tributary of Katakturuk Creek where we examined the Ledge Sandstone, the Fire Creek Siltstone, and the Kemik Sandstone.

Pebble Shale Unit Locality (Houseknecht, Schenk, Mull)

Locality 95-26; GPS- N69,40.78; W145,13.85 (N69,40,47; W145,13,51)
GPS decimal degrees equivalent- N69.6797; W145.2308
Sample Numbers: DH95-49 and DH95-50

We examined a horizontal exposure of the Pebble Shale Unit, which contained a thin fine grained sandstone. Very few pebbles were observed in this exposure, or in any exposure of the Pebble Shale Unit for that matter.

West Fork of Marsh Creek (Houseknecht, Schenk, Mull)

Locality 95-27; GPS- N69,40.82; W144,58.74 (N69,40,49; W144,58,44)
GPS decimal degrees equivalent- N69.6803; W144.9789
Sample Numbers: DH95-51 and DH95-52

We examined the important exposures along the West Fork of Marsh Creek, the type locality of the "Marsh Creek" facies of the Kemik Sandstone. The section began with the Ledge Sandstone (at river level), which is overlain by the Marsh Creek facies of the Kemik Sandstone, and the Pebble Shale Unit. The Marsh Creek facies contains many ironstone units.

East Fork of Marsh Creek (Houseknecht, Schenk, Mull)

Locality 95-28; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489
Sample Numbers: none

We revisited the exposures along the East Fork of Marsh Creek, focusing on the fossils seen just above the LCU, and the Kemik Sandstone resting directly on the Ledge Sandstone. We spent some time recovering pelecypod fossils from the Kemik Sandstone.

We then flew way up on top of the Sadlerochit Mountains to collect an AFTA sample from the Ivishak Formation. From the top we had a beautiful view all the way to the coast and the ice pack.

Crest of Sadlerochit Mountains- AFTA sample (Houseknecht, Schenk, Mull)

Locality 95-29; GPS- N69,38.66; W144,56.55 (N69,38,40; W144,56,33)
GPS decimal degrees equivalent- N69.6444; W144.9425
Sample Number: DH95-53

Fire Creek Canyon (Houseknecht, Schenk, Mull)

We again examined the Ellesmerian section through Fire Creek Canyon, and recovered a block of sandstone float that may have contained possible dinosaur footprints. We also collected two sandstones for AFTA: DH95-54 was from the Ledge Sandstone, and DH95-55 was from the Karen Creek (Sag River) Sandstone.

Locality 95-30; GPS- N69,31.93; W145,12.67 (N69,31,56; W145,12,40)
GPS decimal degrees equivalent- N69.5322; W145.2111
Sample Numbers: DH95-54 and DH95-55

We all returned to Kavik, and the helicopter and pilot were released at noon. All field personnel departed Kavik Camp for Deadhorse via 40-Mile Air, and then to Anchorage via commercial airline. We heard later that the pilot who flew us out of Kavik Camp lost his life in a crash of the very same Cessna two weeks after we left.

AUGUST 10; Thursday

All field personnel departed Anchorage. There were no accidents in the field during 1995, and everyone returned home safely.

FIELD WORK SUMMARY, JULY 28 - AUGUST 14, 1996

The following is a summary of the two field sessions undertaken in ANWR between July 28 and August 14, 1996. The first session (July 28-August 4) focused on geochemical and structural studies, and the second session (August 4-14) focused on sedimentologic and stratigraphic studies. All rock samples collected during this time are stored at the USGS in Reston, Virginia.

Field Personnel- First Session, July 28-August 4, 1996

Robert C. Burruss (USGS, Denver)
John Kelley (USGS, Anchorage)
Shelley Orth (NAGT intern, USGS, Denver)
Gary Solin (USGS WRD, Anchorage)
Bronwen Wang (USGS WRD, Anchorage)

JULY 27, 1996, Saturday

All field personnel assembled in Anchorage, Alaska.

JULY 28, Sunday

All field personnel traveled from Anchorage to Deadhorse on commercial airline, and traveled to Kavik Camp in three groups (because of all the gear) via Cape Smythe Air Cessna 207. We attempted an overflight of the field area along the north slope of the Sadlerochit Mountains in ANWR, with a return west through the Ignek Valley. A low ceiling forced us to return along the northern slope of the Sadlerochit Mountains. An effort was made during this session to sample springs and rivers in ANWR for baseline geochemistry.

Logistical Support

Kavik Camp Manager: Sami Superdock
Cape Smythe Air pilots: Gerry Moriarity, Maryann Waad
Air Logistics helicopter (N130AL) pilot: Jim Spraggins

JULY 29, Monday

Today brought rain, a low ceiling, and no flying. All field work was canceled.

JULY 30, Tuesday

Today brought rain, snow, a low ceiling, and no flying. All field work was canceled.

JULY 31, Wednesday

Morning brought rain and a low ceiling, but weather improved in late morning. At about noon Burruss, Wang, and Solin traveled to Red Hill Spring to begin sampling for baseline geochemical studies (Figure FS7). We then traveled to outcrops of Sagavanirktok Formation ("Stonehenge") near Kavik Camp to sample oil-stained sandstones (Figure FS8).

Red Hill Spring (Wang, Solin, Burruss)

Locality 96-1; GPS- N69,37.63; W146,01.92 (N69,37,38; W146,01,55)
GPS decimal degrees equivalent- N69.6272; W146.0319
Water Sample ID: 693737146013801

Sagavanirktok Formation ("Stonehenge") near Kavik (Burruss, Solin, Wang)

Locality 96-2; GPS-N69,39.19; W146,43.24 (N69,39,11; W146,43,14)
GPS decimal degrees equivalent- N69.6531; W146.7206
Sample Numbers: 96RCB1, 96RCB2

AUGUST 1, Thursday

The morning brought nice weather, finally. Wang and Solin traveled to Hue Creek with all of the gear to begin water sampling for baseline geochemical studies. Burruss, Orth, and Kelley traveled to the East Fork of Marsh Creek to review the geology, then traveled to Hue Creek to do the same. A magnetometer traverse was begun at Hue Creek.

East Fork of Marsh Creek (Burruss, Orth, Kelley)

Locality 96-3; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489
Sample Numbers: none

Hue Creek (Burruss, Orth, Kelley, Wang, Solin)

Locality 96-4; GPS- N69,34.17; W145,48.73 (N69,34,10; W145,48,44)
GPS decimal degrees equivalent- N69.5694; W145.8122
Sample Numbers: 96RCB3 to 96RCB7

AUGUST 2, Friday

We had another day of good weather. Wang and Solin traveled to Hue Creek to finish water sampling, and then they traveled to Sadlerochit Spring for water sampling. Burruss and Orth finished the magnetometer traverse at Hue Creek, sampled the Canning turbidites, and then traveled to East Fork of Marsh Creek to examine the Kemik Sandstone duplexes. Meanwhile, Kelley examined the lower Paleozoic section on the West Fork of Marsh Creek.

Hue Creek (Wang, Solin, Burruss, Orth)

Locality 96-4; GPS- N69,34.17; W145,48.73 (N69,34,10; W145,48,44)
GPS decimal degrees equivalent- N69.5694; W145.8122
Sample Numbers: 96RCB8-12
Water Sample ID: Hue Creek above Hue Shale- 693324145495700; Hue Creek within Hue Shale- 693331145495600; Hue Creek below Hue Shale- 693404145481800

Sadlerochit Spring (Wang, Solin)

Locality 96-5; GPS- N69,39.23; W144,23.37 (N69,39,14; W144,23,22)
GPS decimal degrees equivalent- N69.6539; W144.3894
Water Sample ID: 693923144233701

AUGUST 3, Saturday

Low ceiling and rain associated with a fast-moving front meant no flying until late morning. The low ceiling also meant that Kelley could not get back to Marsh Creek. Burruss, Orth, and Kelley traveled to the Katakturuk River "South" oil stained sandstone locality in Canning turbidites (sample 96RCB13), which were found not to be oil stained. We then traveled to the Canning River and sampled the oil stained Sagavanirktok Formation (Figure FS9; sample 96RCB14; see 1997 description of "Navy Section"). We then traveled to the Kemik duplexes on the Canning River and sampled fracture fills (sample 96RCB15). Burruss, Wang, and Solin flew to Hulahula River Spring and Nularvik River Spring in reconnaissance (Figure FS10).

Katakturuk River "South" Canning turbidites (Burruss, Orth, Kelley)

Locality 96-6; GPS- N69,42.88; W145,26.15 (N69,42,53; W145,26,09)
GPS decimal degrees equivalent- N69.7147; W145.4358
Sample Numbers: 96RCB13

"Navy" Section- Sagavanirktok Formation (Burruss, Orth, Kelley)

Locality 96-7; GPS- N69,39.22; W146,14.55 (N69,39,13; W146,14,33)
GPS decimal degrees equivalent- N69.6536; W146.2425
Sample Numbers: 96RCB14

Kemik Sandstone duplexes on Canning River (Burruss, Orth, Kelley)

Locality 96-8; GPS- N69,27.85; W146,20.45 (N69,27,51; W146,20,27)
GPS decimal degrees equivalent- N69.4642; W146.3408
Sample Numbers: 96RCB15

AUGUST 4, Sunday

We had some excitement today as a grizzly appeared in camp in the morning. Warning shots resulted in his departure. At noon all field personnel traveled from Kavik Camp to Deadhorse via Cape Smythe Air, and met up with second session personnel for a few minutes in the airport in Deadhorse. All first session personnel traveled to Anchorage.

Field Personnel- Second Session, August 3-14, 1996

Frances Cole (Stanford University)
David W. Houseknecht (USGS, Reston)
Naresh Kumar (consultant, Dallas)
C. Gil Mull (Alaskan Survey, Fairbanks)
Christopher J. Potter (USGS, Denver)
Christopher J. Schenk (USGS, Denver)

AUGUST 3, Saturday

All second-session field personnel traveled to Anchorage.

AUGUST 4, Sunday

All second-session field personnel traveled to Deadhorse via commercial airline, and traveled to Kavik Camp via Cape Smythe Air Cessna 207 in two groups, arriving in late afternoon in light rain. The helicopter had arrived earlier, and we had the pilot sling-load 2 barrels of fuel to cache at Jago/Bitty. All first-session field personnel traveled from Kavik to Deadhorse, then to Anchorage. The same grizzly that was chased away by the first group came way too close to camp at about midnight. This was a very unwise decision.

AUGUST 5, Monday

East Fork of Marsh Creek (Houseknecht, Schenk, Potter)

Locality 96-9; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489
Sample Numbers: 96DH-1 (Echooka Fm.)

We first went upstream, looking at the Ledge Sandstone Member, then we walked up the unconformity between the Ledge Sandstone Member of the Ivishak and the Kemik Sandstone. We continued to the east following Decker's suggestion that the unconformity was better exposed, but, finding only covered slope, we instead walked south to the unconformity on top of the Lisburne Group, and measured a thin section of Echooka Formation. We continued down the drainage, going through the Kavik Shale Member, and gradationally into the Ledge, which was nicely exposed in a narrow gorge with waterfalls. Jim picked us up a short time later as the weather was deteriorating rapidly, before the section could be measured in detail. The Kemik Sandstone at this locality is definitely resting on the Ledge Sandstone; later DH found this relationship nicely exposed in the outcrop on the west side of the river, at river level. We then flew east and south through Sunshine Pass to the Last Creek section, landing on a saddle west of the main ridge in a very strong wind. We reconnoitered the ridge for tomorrow.

Last Creek Reconnaissance (Houseknecht, Schenk, Potter)

Locality 96-10; GPS- N69,37.92; W144,26.89 (N69,37,55; W144,26,53)
GPS decimal degrees equivalent- N69.6319; W144.4481
Sample Numbers: 96DH-2 to 96DH-5

In a very strong wind we examined the Shublik Formation, Kemik Sandstone, and Pebble Shale Unit on the ridge to the north above Last Creek. The Kemik overlies the Shublik at this locality. We decided to measure this section in detail tomorrow, and then flew southwest to reconnoiter the Arctic Creek facies.

Arctic Creek Facies Reconnaissance (Houseknecht, Schenk, Potter)

Locality 96-11; GPS- N69,32.84; W144,39.68 (N69,32,50; W144,39,41)
GPS decimal degrees equivalent- N69.5472; W144.6614
Sample Numbers: 96DH-6 and 96DH-7

We landed and noted that all exposures of sandstone were extremely frost shattered, with very little bedding visible. Despite traversing the main outcrop area, we did not observe the turbidites that were previously described from this locality. We concluded that no more time should be spent on Arctic Creek facies this field session. We flew back to Kavik in low clouds, limited visibility, and rain.

AUGUST 6, Tuesday

Last Creek, at river level (Houseknecht, Schenk, Kumar)

Locality 96-12; GPS- not recorded
Sample Numbers: 96DH-8 to 96DH-18

We did a quick fly-by for photographs (Figure FS11), and then we were dropped off on the west side, at river level, at 11:30 am. The weather and the need to ferry the other group put us on the rock much later than we wanted to be. The section began with the Ledge Sandstone, the Fire Creek Siltstone, the Shublik Formation, the Kemik Sandstone, and the pebble shale unit. We quickly measured through the Ledge, Fire Creek, and Shublik to get to the Kemik. About 80' of section below the Kemik was covered as we traversed east to the Kemik, and we later called this the "Gap Section". We then measured the Kemik Sandstone in detail, and measured as far above the Kemik Sandstone as we could from the base of this section. The Kemik at this section is what Mull terms the Ignek Valley Member.

Mt. Weller area (Potter, Mull, Cole)

Locality 96-13; GPS- not recorded
Sample Numbers: 96FC-26 (AFTA)

We noted steep north dipping cleavage and tight chevron folds in the argillites of the Nerukpuk Formation in the Mt. Weller area. The sample for AFTA was from clean quartzite of the Nerukpuk. We were in the vicinity of the Weller Thrust. North of the fault was steeply dipping Lisburne Group, and south of the fault was gently dipping Nerukpuk Formation.

Last Creek and "West Face" of Last Creek (Potter, Mull, Cole)

Locality 96-14; GPS- not recorded
Sample Numbers: none

We then flew back to Last Creek on the east end of the Sadlerochit Mountains. We started at the Ledge Sandstone and examined the section through to the Kemik Sandstone. We then moved to "West Face" of Last Creek and examined the Kemik Sandstone, and noted that there are two faults between this section and Last Creek. From here we flew to the East Fork of Marsh Creek.

East Fork of Marsh Creek (Potter, Mull, Cole)

Locality 96-15; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489
Sample Numbers: none

We examined the imbricates of the Kemik Sandstone. The Kingak Shale in this area is highly deformed reflecting complex deformation. From here we returned to Kavik.

AUGUST 7, Wednesday

Last Creek, "Gap" Section (Houseknecht, Schenk, Kumar)

Locality 96-16; GPS- N69,37.92; W144,39.68 (N69,37,55; W144,39,41)
GPS decimal degrees equivalent- N69.6319; W144.6614
Sample Numbers: 96DH-19 to 96DH-23

We were dropped off on the saddle west of the high point on the ridge to measure the "Gap" section that was not measured yesterday. Following that, we spent some energy trying to see if the thickness of the Shublik Formation changed along the outcrop, which it did, suggesting that the LCU was erosive into the Shublik at this section. We collected three ammonites from the Shublik Formation. We then hiked west across the thrust to measure a nice exposure of west-facing Ignek Valley Member of the Kemik Sandstone, which we called the "West Face, Last Creek" Section.

"West Face, Last Creek" Section (Houseknecht, Schenk, Kumar)

Locality 96-17; GPS- not recorded
Sample Numbers: 96DH-24 to 96DH-28

We measured the West Face Section, which is one of the thickest outcrop sections of the Kemik Sandstone. The base of the Kemik was not exposed. After measuring the Kemik, we traversed across a steep slope to the south to find what we remembered seeing from the air as Kingak Shale, but the slope was deeply covered with Kemik float and weathered shale. The helicopter arrived at this point, and we then flew along the exposures of Kemik on the east side of the Sadlerochit River, and determined that the southernmost exposure of the Kemik should be measured.

Sadlerochit River #1 (Houseknecht, Schenk, Kumar)

Locality 96-18; GPS- N69,37.07; W144,25.55 (N69,37,04; W144,25,33)
GPS decimal degrees equivalent- N69.6178; W144.4258
Sample Numbers: 96DH-29 to 96DH-33

The outcrop is the northernmost exposure of the Kemik, on the east side of the river, but south of the Last Creek section. We named this the "Sadlerochit River #1 Section". We measured the Kemik Sandstone and continued up into the Pebble Shale Unit with all of the well-exposed orange-red ironstone horizons (Figure FS12). There is a recumbent fold just south of this section. (NOTE: the cover of the July 1990 AAPG Bulletin, volume 74/7, is a photo of this fold).

Hue Creek (Potter, Cole)

Locality 96-19; GPS- N69,34.17; W144,48.73 (N69,34,10; W145,48,44)
GPS decimal degrees equivalent- N69.5694; W145.8122
Sample Numbers: none

We examined the Hue Shale and its deformation, and we examined the thrust between the Katakuruk Dolomite and the Ellesmerian rocks. We then were flown to the head of Katakturuk Canyon to begin a traverse from south to north.

Katakturuk River Canyon (Potter, Cole)

Locality 96-20; GPS- not recorded
Sample Numbers:

We noted strong angular unconformity between the Nanook Dolomite and the Lisburne, without much evidence of Kekiktuk. We examined the Ledge Sandstone, Kavik Shale, Echooka Formation at the beginning of the canyon, as well as the Lisburne Group. Most of the canyon is in the Katakturuk Dolomite. We traversed through the canyon to the north. We saw what was mapped as Kemik Sandstone northwest of the mouth of the canyon.

AUGUST 8, Thursday

"Horseshoe" Section (Houseknecht, Schenk, Kumar)

Locality 96-21; GPS- N69,33.39; W145,27.46 (N69,33,23; W145,27,28)
GPS decimal degrees equivalent- N69.5564; W145.4578
Sample Numbers: 96DH-34 to 96DH-42

We were dropped off at the base of the Kemik "horseshoe" or "shovel" in the central part of the Ignek Valley, at river level after flying to and circling Ignek Mesa. We measured up the prominent south-facing chute on the western end of the outcrop where someone had drilled plugs. This section is the type section of the Kemik Sandstone as designated by Mull in 1987. We then traversed northwest across to the Kemik on the other end of the horseshoe, which was poorly exposed. We then hiked downriver to the next exposure of the Kemik, which we called "Bear Ridge"(Figure FS13).

"Bear Ridge" Section (Houseknecht, Schenk, Kumar)

Locality 96-22; GPS- not recorded
Sample Numbers: 96DH-43 to 96DH-46.

We left our packs at the base and hiked up the ridge to the west to examine the contact between the Kemik and the pebble shale. A partial section was measured at the top, and we spent some time digging out the contact between the Kemik and the pebble shale unit. Work stopped for a time as a large grizzly came down the river directly towards us. We formed a committee to try and decide what to do. After discussing the "shoot it out" option, cooler heads prevailed, and DH and NK began talking soothingly to the creature, who, upon hearing words, stopped, looked, and then ran north for the hills. After the excitement, we went back to the base of the ridge, traversed along the base of the Kemik, and we found the LCU and the Kingak Shale. We measured a partial section of the Kemik. We then took our packs and hiked west through the tussocks to the next drainage, where the Kemik was exposed in near vertical beds. For ease of memory, we called this the "Vertical Kemik" Section.

"Vertical Kemik" Section (Houseknecht, Schenk, Kumar)

Locality 96-23; GPS- N69,33,.55; W145,29.67 (N69,33,33; W145,29,40)
GPS decimal degrees equivalent- N69.5592; W145.4944
Sample Numbers: 96DH-47 to 96DH-53

This outcrop has a nice exposure of the Kingak Shale-Kemik Sandstone contact, which is the LCU. The upper part of the Kemik was rubbly, and poorly exposed. The Kingak Shale contains several of the ironstones that are also common in the Kemik and Pebble Shale Unit (Figure FS14).

Okpilak Batholith (Potter, Cole, Mull)

Locality 96-24; GPS- not recorded
Sample Numbers: none

We traveled to the northeast margin of the Okpilak Batholith above the Jago River drainage. The batholith is variably foliated and in places mylonitic. Much of the foliation has a steep to moderate dip to the south. To the north the granite is overlain by 3 meters of coarse grained Kekiktuk conglomerate,

followed by the Lisburne with quartz pebble horizons. Curiously, there is no K-spar in the Kekiktuk or Lisburne pebble beds given the supposed local source.

Aichilik River (Potter, Cole, Mull)

Locality 96-25: GPS- not recorded
Sample Numbers: none

We examined pre-Missisippian turbidites deformed by northeast trending folds with well developed axial-plane cleavage. We then moved to the Egaksrak River near the Leffingwell Ridge.

Egaksrak River near Leffingwell Ridge (Potter, Cole, Mull)

Locality 96-26; GPS- not recorded
Sample Numbers: none

In this area Hanks mapped a thrust that placed the Lisburne Group over the Permo-Triassic rocks. We examined all units exposed in the area and we were not convinced that this was a true klippe, we confirmed that there must be a north-dipping thrust under the Lisburne, but we were not sure if it was a back thrust or a north-directed thrust that was folded. We had nice views of the steeply dipping to overturned Ellesmerian on Leffingwell Ridge as were made our way back to Kavik.

AUGUST 9, Friday

All travel and field work was cancelled due to snow.

AUGUST 10, Saturday

Today F. Cole, C. Potter, N. Kumar, and G. Mull traveled to Deadhorse at noon via Cape Smythe Air, and then flew to Anchorage via commercial airline. Houseknecht and Schenk continued the field work. From the air we saw several grizzlies trudging through the snow.

Echooka Point (Houseknecht and Schenk)

Locality 96-27; GPS- N69,18.67; W147,42.57 (N69,18,40; W147,42,34)

GPS decimal degrees equivalent- N69.3111; W147.7094
Sample Numbers: 96DH-54 to 96DH-73

On a very winter-like day we flew west to the Echooka River section of the Kemik Sandstone recommended by both Decker and Mull. The pilot left us and flew to Pump Station 4 for helicopter maintenance. We measured the unusual Kemik section, unusual in that there appears to be a gradation between the Kingak and the Kemik, with a few additional fine-grained members of the Kemik (Figure FS15). After measuring the section, we hiked north up-river about a mile to examine Hue Shale and Canning turbidite sections. The Hue Shale locality was quarter-mile south of the Canning turbidite locality.

Hue Shale section on Echooka River (Houseknecht and Schenk)

Locality 96-28; GPS- not recorded
Sample Number 96DH-74

Canning turbidite locality on Echooka River (Houseknecht and Schenk)

Locality 96-29; GPS- N69,19.15; W147,40.44 (N69,19,09; W147,40,26)
GPS decimal degrees equivalent- N69.3192; W147.6739
Sample Numbers: 96DH-75 and 96DH-76

This section was not measured, but sampled for vitrinite and petrography. This section was dominated by typical thin-bedded Canning turbidites. Today was a very cold day in the field. Jim returned at 4:00 pm sharp from Pump Station 4, and we headed for the locality of the Kemik Sandstone on the Shaviovik River mentioned by Gil Mull. The locality was called the "Shaviovik" Section.

"Shaviovik" Section (Houseknecht and Schenk)

Locality 96-30; GPS- N69,20.56; W147,12.56 (N69,20,34; W147,12,34)
GPS decimal degrees equivalent- N69.3428; W147.2094
Sample Numbers: 96DH-77 to 96DH-81

We measured this unusual section that includes a thin Kemik Sandstone. This section appeared to have Kingak Shale followed by Kemik Sandstone

with a possible paleosol between. We need to take another look at this section. This and other sections of the Kemik Sandstone west of the Canning River appear very different from sections east of the Canning.

AUGUST 11, Sunday

Sadlerochit River #2 Section (Houseknecht and Schenk)

Locality 96-31; GPS- N69,36.81; W144,27.75 (N69,36,49; W144,27,45)
GPS decimal degrees equivalent- N69.6136; W144.4625
Sample Numbers: 96DH-82 to 96DH-90

We returned to the south end of the Kemik Sandstone exposures on the east side of the Sadlerochit River, and measured the Kemik section in the southernmost prominent chimney, and we continued as far up section as possible into the Pebble Shale Unit. We then flew north to look at Kemik along the plunging nose of the Sadlerochit Mountains, on the east side of the Sadlerochit River. We decided to measure a section across the river, opposite Sadlerochit Spring.

Sadlerochit Spring Section (Houseknecht and Schenk)

Locality 96-32; GPS- N69,39.52; W144,23.08 (N69,39,31; W144,23,05)
GPS decimal degrees equivalent- N69.6586; W144.3847
Sample Numbers: 96DH-91 to 96DH-97

This section was structurally complicated, and we measured a section beginning at what we thought was Ledge Sandstone, but it all may have been Kemik Sandstone (Figure FS16). Structure here has really buggered up the sandstone. We then flew northeast to the Jago/Bitty cache where we re-fueled, and flew the Sabbath Creek section in reconnaissance, noting from the air that Jago/Bitty Bluff contained recumbent folds in the Paleocene clastics. We then flew back to the East Fork of Marsh Creek, where we measured a section of the Kingak-Kemik at the spot where we saw the wolverine last year.

"Wolverine" Section (Houseknecht and Schenk)

Locality 96-33; GPS- N69,41.58; W144,51.88 (N69,41,35; W144,51,53)
GPS decimal degrees equivalent- N69.6931; W144.8647

Sample Numbers: 96DH-98 through 96DH-101

We measured the Kingak Shale and the Kemik Sandstone. This section is remarkable in the amount of Kingak Shale that is exposed below the Kemik. Then, we hopped upriver a few hundred yards, back to the unconformity locality of the first day. We measured a section through the LCU and up into the Pebble Shale Unit (Figure FS17).

"Unconformity" Section (Houseknecht and Schenk)

Locality 96-34; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489
Sample Numbers: 96DH-102 and 96DH-103

We quickly revisited this section, and DH found the unconformity nicely exposed at river level on the west side of the river. On west side of creek, the LCU is sandstone-on-sandstone, and can be recognized based on distinctive sandstone compositions. This demonstrates that the LCU is downcutting sharply from east to west at this location.

AUGUST 12, Monday

Jago/Bitty Bluff (Houseknecht and Schenk)

Locality 96-35; GPS- N69,37.55; W143,40.52 (N69,37,33; W143,40,31)
GPS decimal degrees equivalent- N69.6258; W143.6753
Sample Numbers: 96DH-104 and 96DH-105

We returned to the Jago/Bitty Bluff to look at the recumbently folded Paleocene clastics (Figure FS18). The section was sampled for vitrinite and petrography but not measured; we determined that some of the beds were overturned. Every mosquito in Alaska greeted us at this locality. We then crossed the Jago River, and headed east for the Sabbath Creek section of Paleocene. Our stops are labeled Jago River 1, 2, 3, 4, and 5.

Jago River #1 (Houseknecht and Schenk)

Locality 96-36; GPS- N69,37.42; W143,34.64 (N69,37,25; W143,34,38)
GPS decimal degrees equivalent- N69.6236; W143.5772
Sample Numbers: 96DH-106 to 96DH-108

The first stop was at a section of amalgamated fluvial channel sandstones overlain by possible overbank mudstones. We measured a partial section of the Paleocene.

Jago River #2 (Houseknecht and Schenk)

Locality 96-37; GPS- N69,39.54; W143,32.57 (N69,39,32; W143,32,34)
GPS decimal degrees equivalent- N69.6589; W143.5428
Sample Numbers: DH96-109 to DH96-112.

The second stop featured nearly all conglomerate beds and conglomeratic sandstones separated by long covered slopes. We measured a partial section in this area. It is very difficult to tell if the conglomerate beds are overturned or not as none of the contacts are exposed, and the coarse grained disorganized fabrics are no help (Figure FS19).

Jago River #3 (Houseknecht and Schenk)

Locality 96-38; GPS- N69,39.89; W143,31.28 (N69,39,53; W143,31,17)
GPS decimal degrees equivalent- N69.6647; W143.5214
Sample Numbers: 96DH-113 to 96DH-115

This stop was a few hundred yards from the last; the section was not measured but was sampled for petrography. This was a similar exposure to the previous one in that there were long covered slopes broken by outcrops of conglomerate.

Jago River #4 (Houseknecht and Schenk)

Locality 96-39; GPS- N69,41.15; W143,29.43 (N69,41,09; W143,29,26)
GPS decimal degrees equivalent- N69.6858; W143.4906
Sample Numbers: 96DH-116 and 96DH-117

We made a brief stop near the end of the Sabbath Creek outcrop belt where we landed above a cut-bank, walked down a small ravine to the cut-bank, and examined dark gray, fine-grained sandstone within a gray shale exposure. We collected shale for vitrinite and a sandstone sample for petrography.

Jago River #5 (Houseknecht and Schenk)

Locality 96-40; GPS- N69,41.40; W143,29.68 (N69,41,24; W143,29,41)
GPS decimal degrees equivalent- N69.6900; W143.4947
Sample Numbers: 96DH-118

We made one more stop very near the end of the Sabbath Creek outcrop. The exposure consisted of conglomerate and cross-bedded pebbly sandstone. We saw something resembling a bone embedded in the conglomerate. We then flew north up the Jago River to the Niguanak area.

Canning Formation on Niguanak High (Houseknecht and Schenk)

Locality 96-41; GPS- N69,55.04; W143,22.70 (N69,55,02; W143,22,42)
GPS decimal degrees equivalent- N69.9172; W143.3783
Sample Numbers: 96DH-119

This site was several miles down the Jago River to locate some mapped oil-bearing sandstone. The sandstones were located on an east-facing bluff; the sandstones looked concretionary, and the rock was essentially float at river level. The sandstones had a very strong petroleum odor. The helicopter pilot was impressed.

From here we flew down the Jago River, refueled at the USFWS facility at Kaktovik, and then headed west. First, we flew over the KIC well site. On the way out we observed a large grizzly digging for something on the beach. We continued west and stopped at several sites along the Marsh Creek anticline to collect sandstone samples (Figure FS20). From the air several sandstone hogbacks are visible along the crest of the breached Marsh Creek Anticline, but on the ground nearly all of these outcrops turn out to be unconsolidated sands.

Marsh Creek Anticline #1 (Houseknecht and Schenk)

Locality 96-42; GPS- N69,54.27; W144,39.91 (N69,54,16; W144,39,55)
GPS decimal degrees equivalent- N69.9044; W144.6653
Sample Number: 96DH-120

The outcrop is Tertiary sandstone, mostly unconsolidated, locally pebbly; we attempted to sample but not sure if it will survive shipping. This stuff really

needs to be trenched, as the surface is covered with a foot of weathered sediment. Apparently, Fouch and his field party sampled this very outcrop a few years ago. At this locality we saw a sow with three cubs.

Marsh Creek Anticline #2 (Houseknecht and Schenk)

Locality 96-43; GPS- N69,55.90; W144,39.91 (N69,55,54; W144,39,55)
GPS decimal degrees equivalent- N69.9317; W144.6653
Sample Number: 96DH-121

This outcrop is mapped as Canning Formation, but all sandstones are float, and nothing appeared to be in place. We collected one sample.

Marsh Creek Anticline #3 (Houseknecht and Schenk)

Locality 96-44; GPS- N69,56.74; W144,39.86 (N69,56,44; W144,39,52)
GPS decimal degrees equivalent- N69.9456; W144.6644
Sample Number: 96DH-122

Again, this outcrop is Tertiary sandstone, friable, and locally pebbly. We could not collect friable sand. Instead, we sampled a very thin bed of tight sandstone.

AUGUST 13, Tuesday

West Fork of Marsh Creek (Houseknecht and Schenk)

Locality 96-45; GPS- N69,40.78; W144,58.75 (N69,40,47; W144,58,45)
GPS decimal degrees equivalent- N69.6797; W144.9792
Sample Numbers: 96DH-123 to 96DH-132

We went back to a location Gil Mull took us to last year. The section begins with the Ledge Sandstone, and goes into Mulls' type section of the Marsh Creek Member of the Kemik. We measured the section. Significantly, this is one of the few exposures that has no massive Kemik sandstone. We collected several samples from the Ledge Sandstone to evaluate diagenesis immediately below the LCU. Jim returned, and we flew west to another of Mulls' localities where he interpreted a rooted sandstone (Figure FS21).

"Rooted Sandstone" Section (Houseknecht and Schenk)

Locality 96-46; GPS- N69,39.57; W145,17.80 (N69,39,34; W145,17,48)
GPS decimal degrees equivalent- N69.6594; W145.2967
Sample Numbers: 96DH-133 to 96DH-135

We measured the section. This section also contains the Ledge Sandstone below the so-called rooted sandstone. We then flew to the Kemik Sandstone duplex on the Canning River, where Jim dropped us off and coaxed two big grizzlies away from our location.

Kemik Sandstone on Canning River (Houseknecht and Schenk)

Locality 96-47; GPS- N69,30.59; W146,18.68 (N69,30,35; W146,18,41)
GPS decimal degrees equivalent- N69.5097; W146.3114
Sample Numbers: 96DH-136 to 96DH-142

We measured the section in a steep, south-facing gully full of willows. This is the northernmost of the large Kemik exposures on the Canning, just north of the prominent duplex. We then flew up the Ignek Valley to measure a thin Kemik section.

"Thin Kemik" Section (Houseknecht and Schenk)

Locality 96-48; GPS- N69,35.27; W145,56.87 (N69,35,16; W145,56,52)
GPS decimal degrees equivalent- N69.5878; W145.9478
Sample Numbers: 96DH-143 to 96DH-145

We measured a thin section of the Kemik in the west end of the Ignek Valley, and then flew down the Katakturuk River (Figure FS22) to a few Tertiary localities, the first of which had been drilled for plugs by unknown persons. The second was an exposure of Canning turbidites, some of which were supposed to be oil bearing.

Canning on Katakturuk River #1 (Houseknecht and Schenk)

Locality 96-49; GPS- N69,42.88; W145,26.15 (N69,42,53; W145,26,09)
GPS decimal degrees equivalent- N69.7147; W145.4358
Sample Numbers: 96DH-146 to 96DH-148

We stopped to sample Canning Formation turbidites, labeled as "lightly oil stained" on Bader and Bird map. We found oil stain and odor in turbidite beds near south end of exposure and collected some representative samples. We measured the section very quickly.

Canning on Katakturuk River #2 (Houseknecht and Schenk)

Locality 96-50; GPS- N69,42.92; W145,25.91 (N69,42,55; W145,25,55)
GPS decimal degrees equivalent- N69.7153; W145.4319
Sample Numbers: 96DH-149 and 96DH-150

We stopped to examine and sample the turbidites near the north end of mapped exposure of Canning Formation. We found no oil stain or oil odor.

Canning on Katakturuk River #3 (Houseknecht and Schenk)

Locality 96-51; GPS- N69,45.49; W145,19.67 (N69,45,29; W145,19,40)
GPS decimal degrees equivalent- N69.7581; W145.3278
Sample Numbers: 96DH-151 and 96DH-152

We stopped at the exposure of the Canning Formation at the confluence of Katakturuk and Nularvik rivers. We sampled thick (4 ft+), possibly channelized turbidites for petrography and for vitrinite reflectance.

Oil-bearing sandstone, Marsh Creek Anticline (Houseknecht and Schenk)

Locality 96-52; GPS- N69,52.25; W145,10.73 (N69,52,15; W145,10,44)
GPS decimal degrees equivalent- N69.8708; W145.1789
Sample Numbers: 96DH-153

We continued north down the Katakturuk River and sampled a Tertiary sandstone near the axis of the Marsh Creek Anticline. The sandstones were oil bearing, in fact the outcrop looked like a tar sand, but had no odor. This exposure of sandstone was sampled by Gautier and others in 1995 (Figure FS23). We flew home to Kavik amazed that there is really no surficial evidence of seismic lines having been shot in ANWR compared to the state lands.

AUGUST 14, Wednesday

After releasing the helicopter in the morning, we traveled from Kavik Camp to Deadhorse via Cape Smythe Air in heavy rain and very limited visibility, and finally we traveled from Deadhorse to Anchorage via commercial airline. There were no accidents in the field in 1996, and everyone returned home safely. After leaving us, Jim Spraggins flew up the Canning River to sling-load a small plane to Happy Valley that crashed the previous week.

FIELD WORK SUMMARY- JULY 5-14, 1997

The ANWR field work in 1997 was divided into two sessions. A session in July focused on the structural and geochemical issues, and an August session was devoted to sedimentologic and stratigraphic studies. The sedimentologic and stratigraphic studies focused on outcrops that will assist us in interpreting the seismic data.

Field Personnel- First Session, July, 1997

Robert C. Burruss (USGS, Reston)
Thomas Moore (USGS, Menlo Park)
Christopher J. Potter (USGS, Denver)

JULY 5, 1997; Saturday

All field personnel traveled to Anchorage.

JULY 6; Sunday

All field personnel traveled from Anchorage to Deadhorse via commercial airline, and then to Kavik Camp via Cape Smythe Air. We took a detour along the coast to the northeast end of the Marsh Creek Anticline, then we flew down the axis of anticline back to Kavik Camp. We had a nice overview of the anticline. The helicopter arrived today.

Logistical Support

Kavik Camp Manager: Steve Winfield
Cape Smythe Air pilots: Gerry Moriarity, Kermit Karns
Air Logistics helicopter (N133AL) pilot: Jim Spraggins

JULY 7, Monday

Today brought a cold wind out of north, low clouds and fog, resulting in no flying until noon. We then traveled to the Hue Shale outcrop along the Jago River about 1 pm. We did further reconnaissance along the Jago River and the Niguanak River. We sampled possible Canning sandstones on the Niguanak for reservoir properties, and then we made initial magnetic susceptibility measurements with the hand-held meter.

Hue Shale along Jago River (Potter, Moore, Burruss)

Locality 97-1; GPS- not recorded
Sample Numbers: none

We examined two exposures of the Hue Shale, one of which was dipping 35 degrees to the southwest, and the other was steeply dipping to the north, and was contorted. We concluded that we were looking at the opposite limbs of an asymmetric fold. We then moved 1-2 miles down the Jago and examined an exposure of the Canning Formation. The Canning dips 15 degrees to the north, and we considered that we were looking at the undeformed roof above the passive roof duplex.

Hue Shale, Canning sandstones on Niguanak River (Potter, Moore, Burruss)

Locality 97-2; GPS- N69,53.37; W142,55.41 (N69,53,22; W142,55,25)
GPS decimal degrees equivalent- N69.8894; W142.9236
Sample Numbers: 97CPA1, 97CPA2, 97RCB1-2

We examined the Hue Shale, which was steeply dipping and contorted.

Niguanak Ridge area (Potter, Moore, Burruss)

Locality 97-3; GPS- not recorded
Sample Numbers: unknown

We examined shales and the possible Kingak on the Niguanak Ridge. The Kingak was steeply dipping, folded, black shale with folded calcite veins and

minor bentonitic layers. We also examined Hue Shale north of this exposure.

We flew to Kaktovik to refuel at the USFWS depot. After refueling and receiving a cup of coffee and a tour of downtown Kaktovik from Walt Audi, we traveled part way down the axis of Marsh Creek Anticline, then flew to Sourdough well site on the way back to Kavik. We located the "christmas tree" on the Sourdough well (we assumed this was the No. 3 well (Figure FS24).

JULY 8, Tuesday

Today brought an ominous wind out of the north, with low clouds and fog, resulting in low and slow flying beneath fog. We sampled outcrops along Carter Creek from south to north, ending at measured section of Fouch and others of a few years ago. We collected oriented and grab samples for magnetic analysis by Rich Reynolds. We measured the magnetic susceptibility.

Carter Creek on the Marsh Creek Anticline (Potter, Moore, Burruss)

Locality 97-4; GPS- N69,54.27; W144,39.65 (N69,54,16; W144,39,39)
GPS decimal degrees equivalent- N69.9044; W144.6608
Sample Numbers: CC-1-1 to CC-1-4

Sample CC-1-1 was an oxidized sandstone; CC-1-2 was a brown-gray sandstone, CC-1-3 was a brown sandstone, and CC-1-4 was a yellow oxidized sandstone.

JULY 9, Wednesday

Today again brought wind out of the north with low clouds and fog. We finally took off about 12:30 pm and we attempted to return to Carter Creek, but the fog was too thick and low to make it even as far as the Canning River. We returned to the Sagavanirktok outcrops along the Kavik River southeast of Kavik Camp. Potter and Moore examined the overturned fold, while Burruss sampled the coal bed in the Sagavanirktok Formation for vitrinite reflectance.

Sagavanirktok Formation near Kavik Camp (Potter, Moore, Burruss)

Locality 97-5; GPS- not recorded
Sample Numbers: 97RCB3

The fog lifted some by mid-afternoon, so we again attempted to return to Carter Creek, and got as far as the spot where the Katakturuk River cuts through the Marsh Creek Anticline. The fog was tight against the north flank of the anticline. We examined a small outcrop of possible Canning turbidites and measured magnetic susceptibility. The fog, with rain and a little sleet, got worse, so we had to fly up the Katakturuk drainage to find some clear air to return to camp.

Katakturuk River (Potter, Moore, Burruss)

Locality 97-6; GPS- N69,52.30; W145,10.09 (N69,52,18; W145,10,05)
GPS decimal degrees equivalent- N69.8717; W145.1681
Sample Number: none

JULY 10, Thursday

We made another attempt to return to the Marsh Creek Anticline. The wind was out of the north, with low clouds and fog. We made it to one outcrop, but heavy fog forced us to return to camp.

JULY 11, Friday

We had a busy day, which began with clear skies over Kavik. We flew east over fog filling the Canning River drainage, went through the Ignek Valley and flew all the way to Leffingwell Ridge on the east side of the Aichilik River water gap. We sampled the Lisburne (97RCB4), with photos by Potter and Moore. Fog blew up the ridge, so we had to wait for it to lift before we could fly to the exposures along the west bank of the Aichilik River. There we sampled the fractured Sadlerochit Group and Kingak (97RCB5 to 97RCB12). Potter and Moore sketched and photographed the deformation (Figure FS25). We examined exposure from Lisburne through the Kingak, including an inferred thrust between the Triassic and the Kingak. We observed much internal deformation within all units. In the mid-afternoon we flew to outcrops of the Arctic Creek facies and Kingak on a ridge along the west branches of the headwaters of the Okerokovik

River (97RCB13 to 97RCB16), memorable for the hordes of mosquitoes. We then flew north to Jago/Bitty, where Potter and Moore photographed the recumbent folds. We thought the big fold was a north-verging structure consistent with north-directed thrusting underlying the fold. We then flew down Sabbath Creek for a reconnaissance of the Paleocene section on the way to refuel at the USFWS depot on Kaktovik. We flew over the KIC well site on the way to the Angun Point tar sand locality. At Angun we sampled and photographed the tar sand (Figure FS26) near the location described by Molenaar (97RCB17) on the west side of the lagoon. The sand may be oil-stained but it is friable and not saturated with tar. We flew east to the Kongakut River delta, and made an overflight of the Kongakut aufeis, which is reputed to be the biggest patch of ice on the North Slope. In perfect weather we flew back to Kavik.

Lisburne Group on Aichilik River (Potter, Moore, Burruss)

Locality 97-7; GPS- not recorded
Sample Numbers: 97RCB4

Sadlerochit Group on Aichilik River (Potter, Moore, Burruss)

Locality 97-8; GPS- N69.5300; W143.0695
Sample Numbers: 97RCB5 to 97RCB12

West Branch of Okerokovik River (Potter, Moore, Burruss)

Locality 97-9; GPS- N69.5050; W143.3883
Sample Numbers: 97RCB13 to 97RCB16

Angun Point Tar Sand (Potter, Moore, Burruss)

Locality 97-10; GPS- N69.9180; W142.3950
Sample Numbers: 97RCB17

JULY 12, Saturday

Today brought wind out of the north, with low fog all day, and no flying. All field work was canceled.

JULY 13, Sunday

Today began with wind out of the north, but not too strong, as we could see the Sadlerochit Mountains from camp. Jim agreed to fly before we left camp at noon for Deadhorse, so we flew through Ignek Valley as fog pushed through Katakturuk Canyon. We made a reconnaissance of structure in the Arctic Creek facies and Kingak Hill on the east side of Sadlerochit River as far south as Leffingwell Ridge. We flew back through Ignek Valley, with fog tight against the north face of the Sadlerochit Mountains. Finally, we photographed the Hue Shale and Canning Formation outcrops along Canning River from the helicopter.

Arctic Creek Ridge (Potter, Moore, Burruss)

Locality 97-11; GPS- N69,33.84; W144,39.15 (N69,33,50; W144,39,09)
GPS decimal degree equivalent- N69.5639; W144.6525
Sample Numbers: none

Kingak Shale near Leffingwell Ridge (Potter, Moore, Burruss)

Locality 97-12; GPS- N69,27.91; W144,34.64 (N69,27,55; W144,34,38)
GPS decimal degree equivalent- N69.4653; W144.5772
Sample Numbers: none

We interpreted a possible thrust between the Kingak at this locality and the Arctic Creek at the previous locality.

Arctic Creek above Kekiktuk River (Potter, Moore, Burruss)

Locality 97-13; GPS-69,30.24; W144,44.66 (N69,30,14; W144,44,40)
GPS decimal degree equivalent- N69.5039; W144.7444
Sample Numbers: none

We returned to Kavik at about 12:15 pm and finished packing. Kermit Karns, a new pilot for Cape Smythe, arrived a little after 1:00 pm. We flew beneath lowering clouds and through fog to Deadhorse. By the time the Alaska Air flight from Anchorage was due in Deadhorse the fog was down to the ground. Due to runway construction at Deadhorse, the ILS was off, and jets had to land by VFR. The Alaska Air pilot made two passes over the runway, called it a day and returned to Anchorage. Alaska Air ground crew

said they would divert the Fairbanks-to-Barrow flight to Deadhorse to pick us up around 8 pm. We had dinner at the Prudhoe Bay Hotel (all-you-can-eat). The pilot on the Barrow run made one pass over the airport and continued on to Fairbanks. We thought we heard the passengers cheering. We spent the night at the Prudhoe Bay Hotel.

JULY 14; Monday

Today it rained all morning, which dissipated the fog and raised the ceiling enough so that Alaska Air could actually find the runway at Deadhorse. All field personnel traveled to Anchorage.

FIELD WORK SUMMARY- AUGUST 2-14, 1997

Field Personnel- Second Session, August 2-14, 1997

David W. Houseknecht (USGS, Reston)
Margaret Keller (USGS, Menlo Park)
Mark J. Pawlewicz (USGS, Denver)
Joseph MacQuaker (Univ. of Manchester, UK)
C. Gil Mull (Alaska Survey, Fairbanks)
Christopher J. Schenk (USGS, Denver)

The purpose of this session was to continue stratigraphic and sedimentologic studies of outcrops that directly tie to the seismic grid, and to begin a detailed sequence stratigraphic analysis of the Pebble Shale Unit.

AUGUST 2, Saturday

All field personnel traveled to Anchorage.

AUGUST 3, Sunday

All field personnel traveled from Anchorage to Deadhorse via Alaska Airlines, and then traveled to Kavik Camp in Cessna 207 by Cape Smythe Air (2 trips required). The Jet Ranger was not available until Tuesday (as the Long Ranger we were supposed to have used crashed the previous Friday), so we arranged with Cape Smythe to make two gravel bar landings in the Canning River on Monday the 4th.

Logistical Support

Kavik Camp Manager: Steve Winfield (week 1); Sami Superdock (week 2)
Cape Smythe Air pilot: Kermit Karns
Trans-Alaska helicopter (N86TA) pilot: Craig Wade

AUGUST 4, Monday

The first group (Mull, Keller, MacQuaker) was dropped off at the "Emerald Isle" section in the Canning River to examine the Hue Shale and the Pebble Shale Unit. The second group (Houseknecht, Schenk, Pawlewicz) was dropped (literally) about two miles downstream where an island of Canning Formation is exposed in the east side of the river opposite Nanook Creek, and we called it "Kermit Island" after the pilot. The landing was rough enough to blow out the rear tire. We measured the section, which we considered to be in the Paleocene. Luckily, we were picked up by Craig Wade in the helicopter that evening as the pilot did not come back and pick us up with the Cessna.

“Emerald Isle” section (Keller, MacQuaker, Mull)

Locality 97-14; GPS- not recorded
Sample Numbers: unknown

We began by determining that the Hue Shale was too deformed for detailed analysis, so we focused on the Pebble Shale Unit. We dug a trench through the unit and collected 32 samples through 10 cycles or parasequences. The parasequences are mainly mudstone capped by either stratiform or concretionary mudstone. The parasequences range from a meter to over 2 meters in thickness.

"Kermit Island" Section- Canning Formation (Houseknecht, Schenk, Pawlewicz)

Locality 97-15; GPS- not recorded
Sample Numbers: DH97-1 to DH97-10.

This section was not extensive, but was interpreted to contain an amalgamated sandstone of possible turbidite origin, possibly an amalgamated

turbidite channel sandstone interbedded with thin-bedded turbidites (Figure FS27).

AUGUST 5, Tuesday

The use of the Jet Ranger rather than the Long Ranger meant we had to do more shuttling of people than we had expected to do. We sent Mull and MacQuaker to Marsh Creek to sample the Pebble Shale Unit, Keller and Pawlewicz were sent back to finish sampling the section at "Emerald Isle", and Houseknecht and Schenk measured a section of Canning Formation on the west bank of the Canning River opposite the section measured the previous day. At midafternoon we shuttled Keller and Pawlewicz to the East Fork of Marsh Creek; Houseknecht and Schenk measured a section of Sagavanirktok 1 mile up the Canning River ("Craig Rock" Section), and then we shuttled to Marsh Creek to see what MacQuaker and Keller had interpreted from the Pebble Shale Unit. From there we all shuttled back to Kavik Camp that evening in heavy rain.

East Fork of Marsh Creek (MacQuaker, Mull)

Locality 97-16; GPS- N69,41.06; W144,50.94 (N69,41,04; W144,50,56)
GPS decimal degrees equivalent- N69.6844; W144.8489
Sample Numbers: unknown

We sampled and described several mudstone parasequences in the Pebble Shale Unit and one from the top of the Kemik on the west bank of the East Fork of Marsh Creek.

"Emerald Isle" section (Keller, Pawlewicz)

Locality 97-17; GPS- not recorded
Sample Numbers: unknown

We took seven more samples and finished describing mudstone parasequences in the Pebble Shale Unit.

"Kermit 2" Section- Canning Formation (Houseknecht, Schenk)

Locality 97-18; N69,34.89; W146,18.52 (N69,34,53; W146,18,31)
GPS decimal degrees equivalent- N69.5814; W146.3086

Sample Numbers: DH97-11 to DH97-19.

The Paleocene section at "Kermit 2" contained clinoform facies that are well-represented on the 1002 seismic data set. In a mixed rain and snow storm we measured amalgamated turbidite channel sandstones, thin-bedded turbidites, large-scale low angle truncations, large-scale slump structures in fine-grained sediments, and sampled the sandstones for petrography and the shales for vitrinite and palynology (Figure FS28).

"Craig Rock" Section- Sagavanirktok Formation (Houseknecht, Schenk)

Locality 97-19; GPS- N69,32.51; W146,17.72 (N69,32,31; W146,17,43)
GPS decimal degrees equivalent- N69.5419; W146.2953
Sample Number: DH97-22

This outcrop is mapped as Canning Formation, but the shallow marine origin of the sandstones led to believe that it should be remapped as Sagavanirktok Formation. The sandstones are typical of the marine sandstones found in seismic topset facies in the Paleocene, and these outcrops were directly tied to the subsurface seismic data.

AUGUST 6, Wednesday

Wednesday brought more heavy rain and a low ceiling; we had to wait until mid-morning to begin shuttling. First, Houseknecht , Schenk, and Mull went to a section of deformed Hue Shale along the Canning River, then Houseknecht, Schenk, and Pawlewicz went to a section of Sagavanirktok Formation in the Canning River opposite the Sadlerochit Mountains ("Navy" Section), and Mull, Keller, and MacQuaker traveled to the Hue Creek and "Horseshoe" sections in the Ignek Valley. By 2:00 pm the weather had deteriorated to the point where Houseknecht, Schenk, and Pawlewicz barely made it back to Kavik Camp, and the other three could not be picked up until 8:30 that evening; we thought they were going to spend the night out. An important lesson reaffirmed- always carry survival gear.

Deformed Hue Shale along Canning River (Houseknecht, Schenk, Mull)

Locality 97-20; GPS- N69,36.90; W146,16.81 (N69,36,54; W146,16,49)

GPS decimal degrees equivalent- N69.6150; W146.2803
Sample Numbers: none

We stopped at a section mapped as Hue Shale along the Canning River, but the section was deformed, and very difficult to get any sense of the stratigraphy (Figure FS29). Craig returned with another group, he dropped Pawlewicz with us, and took the others to Hue Creek. He returned and took us to the "Navy" section.

Hue Creek (Keller, MacQuaker, Mull)

Locality 97-21; GPS- N69,34.17; W144,48.73 (N69,34,10; W145,48,44)
GPS decimal degrees equivalent- N69.5694; W145.8122
Sample Numbers: unknown

We examined the Hue Shale and Pebble Shale Unit along the west bank of Hue Creek, but determined that the section was too deformed for detailed sequence analysis.

"Horseshoe" section of Kemik Sandstone (Keller, MacQuaker, Mull)

Locality 97-22; GPS- N69,33.39; W145,27.46 (N69,33,23; W145,27,28)
GPS decimal degrees equivalent- N69.5564; W145.4579
Sample Numbers: unknown

In the rain we examined the type section of the Ignek Valley facies of the Kemik Sandstone. We were almost here for the night.

"Navy" Section- Sagavanirktok Formation (Houseknecht, Schenk, Pawlewicz)

Locality 97-23; GPS- N69,39.12; W146,14.55 (N69,39,07; W146,14,33)
GPS decimal degrees equivalent- N69.6519; W146.2425
Sample Numbers: DH97-27 to 30.

The "Navy" section was a section of Paleocene Sagavanirktok Formation exposed in the cut bank of the Canning River, making it difficult to measure the section as the Canning River was very deep and really moving by the cliff (Figure FS30). We measured what we could reach from re-entrants in

the cliff. We decided to return tomorrow with a raft to attempt to measure the remainder of the section from the river.

AUGUST 7, Thursday

Today, Mull, MacQuaker, and Keller were sent to the West Fork of Marsh Creek, Mull's "rooted section", and a few other localities along the northern side of the Sadlerochit Mountains to sample the Pebble Shale Unit. Houseknecht, Schenk, and Pawlewicz went back to the "Navy" section on the Canning River, which was partially measured using a raft. This section is less than a mile east from the pad of the Exxon Canning River Unit B1 well.

"Navy" Section- Sagavanirktok Formation (Houseknecht, Schenk, Pawlewicz)

Locality 97-24; GPS- N69,39.12; W146,14.55 (N69,39,07; W146,14,33)
GPS decimal degrees equivalent- N69.6519; W146.2425
Sample Numbers: DH97-31 to DH97-38.

Using a small raft, we continued to measure the "Navy" section. Even with the raft the swift flowing water prevented us from measuring all of the section. The upper amalgamated fluvial sandstone in this section is heavily oil stained. The pilot thought what we were doing was crazy (Figure FS31).

West Fork of Marsh Creek (Keller, MacQuaker, Mull)

Locality 97-25; GPS- N69,40.78; W144,58.75 (N69,40,47; W144,58,45)
GPS decimal degrees equivalent- N69.6797; W144.9792
Sample Numbers: unknown

We examined the type section of the Marsh Creek facies of the Kemik Sandstone. We collected several samples from the lowermost Pebble Shale Unit.

AUGUST 8, Friday

Friday brought even more rain, if that was possible. The morning was spent copying field notes, boxing samples, and wondering if the weather would allow the Cessna to arrive from Deadhorse. At noon Mull, Keller,

MacQuaker, and Pawlewicz left Kavik Camp for Deadhorse via Cape Smythe Air (2 trips required). Given the weather and the low ceiling, Houseknecht and Schenk went 5 miles up the Kavik River from camp and measured a partial section of the Canning(?) Formation along the Kavik Syncline in heavy rain.

Kavik Syncline Section- Canning(?) Formation (Houseknecht, Schenk)

Locality 97-26; GPS- N69,36.47; W146,46.88 (N69,36,28; W146,46,53)
GPS decimal degrees equivalent- N69.6078; W146.7814
Sample Numbers: DH97-39 to DH97-42.

This section was interpreted to contain many parasequences of shallow marine to shelf sandstones and mudstones. As such, this is probably an exposure of the Sagavanirktok Formation.

AUGUST 9, Saturday

Today was overcast with a ceiling at 1600', but no rain. The mosquitoes achieved a new level of violence today. Houseknecht and Schenk flew west from Kavik Camp and measured a partial section of Sagavanirktok(?) along the west bank of Juniper Creek, on the north limb of the Shaviovik anticline. The exposure consisted of thick, amalgamated fluvial sands cropping out between long covered intervals. All sandstones were sampled for petrography, and coals were sampled for vitrinite and palynology.

Juniper Creek Section (Houseknecht and Schenk)

Locality 97-27; GPS- N69,33.49; W147,31.86 (N69,33,29; W147,31,52)
GPS decimal degrees equivalent- N69.5581; W147.5311
Sample Numbers: DH97-44 to DH97-55

There were at least eleven sandstones exposed here, with covered slopes between the sandstones. All of the sandstones were interpreted as fluvial in origin. The uppermost sandstone was a beautiful channel sandstone with sets of cross-strata and deformed structures.

Juniper Creek Coal Sample (Houseknecht and Schenk)

Locality 97-28; GPS- N69,35.06; W147,38.93 (N69,35,04; W147,38,56)
GPS decimal degrees equivalent- N69.5844; W147.6489
Sample Number: DH97-56

DH jumped out and collected a coal from a cut-bank along the west side of Juniper Creek. The sample was for vitrinite and palynology.

We then flew west in perfect sunshine and measured a long section of the Sagavanirktok(?) along the Ivishak River.

Ivishak River Section- Sagavanirktok Formation (Houseknecht and Schenk)

Locality 97-29; start of traverse GPS- N69,19.01; W148,12.55 (N69,19,01; W148,12,33), GPS decimal degrees equivalent- N69.3169; W148.2092; end of traverse-GPS- N69,19.15; W148,12.54 (N69,19,09; W148,12,32), GPS decimal degrees equivalent- N69.3192; W148.2089
Sample Numbers: DH97-57-62

This section was a sequence comprised of many shallow marine parasequences. We measured along the west bank of the river. When we ran out of rock, we then flew north along the Ivishak and made several stops to collect coal and sandstone samples.

Coal Sample #1 (Houseknecht and Schenk)

Locality 97-30; GPS- N69,20.53; W148,14.71 (N69,20,32; W148,14,43)
GPS decimal degrees equivalent- N69.3422; W148.2453
Sample Number: DH97-63

Coal Sample #2 (Houseknecht and Schenk)

Locality 97-31; GPS- N69,22.16; W148,15.76 (N69,22,10; W148,15,46)
GPS decimal degrees equivalent- N69.3694; W148.2628
Sample Number: DH97-64

Fluvial sandstone samples- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-32; GPS- N69,22.42; W148,15.29 (N69,22,25; W148,15,17)
GPS decimal degrees equivalent- N69.3736; W148.2547
Sample Numbers: DH97-66, 67, 68

This was an outcrop of overturned beds consisted of fluvial channel sandstones with thin conglomeratic layers right next to prime bear habitat.

We then flew east to Kavik with perfect visibility all the way north to the ice pack. We were amazed at how many gravel landing strips there were on the State lands west of Kavik.

AUGUST 10, Sunday

Our focus today was the Sagavanirktok Formation along the Katakturuk River and its tributaries. We measured partial sections of the Sagavanirktok near the confluence of the Katakturuk and its east tributary. Today was another picture-perfect weather day.

East Katakturuk #1 Section- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-33; GPS- N69,45.26; W145,19.44 (N69,45,16; W145,19,26)
GPS decimal degrees equivalent- N69.7544; W145.3239
Sample Numbers: DH97-69, 70, 71

This thin exposure of the Sagavanirktok Formation was interpreted as a channel sandstone (Figure FS32).

East Katakturuk #2 Section- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-34; GPS- not recorded
Sample Number: DH97-72

We moved a quarter-mile and measured another sandstone that we also interpreted as fluvial in origin. We had visited this exposure two years ago.

We then measured a partial section to the west on a south-facing bluff of what turned out to be Sagavanirktok Formation rather than Canning Formation. This also turned out to be our lunch stop from where we had unparalleled views of the snow-capped Brooks Range.

"Lunch Section"- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-35; GPS- N69,43.39; W145,19.67 (N69,43,23; W145,19,40)
GPS decimal degrees equivalent- N69.7231; W145.3279
Sample Number: DH97-73

This thin section contained shallow marine and possibly tidal deposits.
.
We then moved to the big Canning turbidite exposure on the Katakturuk, but the river level prevented us from measuring a section. We noted many small-scale erosional truncation surfaces in this exposure (Figure FS33).

Canning turbidites on the Katakturuk (Houseknecht and Schenk)

Locality 97-36; GPS- N69,42.88; W145,26.15 (N69,42,53; W145,26,09)
GPS decimal degrees equivalent- N69.7147; W145.4358
Sample Number: DH97-74

We flew to the East Fork of the Tamyariak River and measured a section of the Canning Formation with thin-bedded turbidites.

East Fork Tamyariak River Section- Canning Fm. (Houseknecht and Schenk)

Locality 97-37; GPS- N69,39.44; W145,40.07 (N69,39,26; W145,40,04)
GPS decimal degrees equivalent- N69.6572; W145.6679
Sample Numbers: DH97-75 to 80

This section contained many units of thin-bedded turbidites, mudstone intervals, and an upward increase in the thickness and number of sandstones (Figure FS34). Note: a close-up of this section is displayed on the cover of the AAPG Explorer, April, 1998.

Finally, we flew to the north end of the "Navy" Section to measure and sample the big fluvial sandstone.

North End, "Navy" Section- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-38; GPS- N69,39.73; N146,14.55 (N69,39,44; W146,14,33)
GPS decimal degrees equivalent- N69.6622; W146.2425
Sample Numbers: DH97-82

This exposure consisted of amalgamated sandstones with sets of epsilon cross strata. We returned to Kavik Camp.

AUGUST 11, Monday

Today we flew west in perfect weather to Sagwon Bluffs along the Sagavanirktok River, where we measured a partial section of the Sagavanirktok Formation (Figure FS35). Several of the upper sandstones were oil stained and saturated. These are the oil stained sandstones that figured heavily in the exploration and discovery of Prudhoe Bay field. This classic section of the Sagavanirktok Formation contained several thick coals and fluvial sandstones (Figure FS36). We debated the age of the thick benches of conglomerate lying above the uppermost coal bed. From here we could see dust trails from trucks along the Haul Road.

Sagwon Bluffs (Houseknecht, Schenk)

Locality 97-39; start of traverse- GPS- N69,23.00; W148,42.86 (N69,23,00; W148,42,52), GPS decimal degrees equivalent- N69.3833; W148.7144; end of traverse- GPS- N69,22.96; W148,42.54 (N69,22,58; W148,42,32), GPS decimal degrees equivalent- N69.3828; W148.7089
Sample Numbers: DH97-84 to DH97-93

We then flew east to Kadleroshilik Creek and made three stops. At the first stop we measured a partial section of the Sagavanirktok Formation. The section was adjacent to the trace of an old seismic line that now had a stream running through it, so we called the section "Seismic River". This section contained several cobble and pebble fluvial conglomerates (Figure FS37). We then measured a partial section of the Sagavanirktok at Stop 2, and we hopped over and sampled some sandstones at Stop 3. All of these stops were on state lands, not ANWR.

"Seismic River" Stop #1 (Houseknecht and Schenk)

Locality 97-40; GPS- N69,29.45; W147,49.06 (N69,29,27; W147,49,04)
GPS decimal degrees equivalent- N69.4908; W147.8178
Sample Numbers: DH97-94 to DH97-97

“Seismic River” Stop #2 (Houseknecht and Schenk)

Locality 97-41; GPS- N69,29.21; W147,48.31 (N69,29,13; W147,48,19)
GPS decimal degrees equivalent- N69.4869; W147.8053
Sample Numbers: none

“Seismic River” Stop #3 (Houseknecht and Schenk)

Locality 97-42; GPS- N69,28.59; W147,44.42 (N69,28,35; W147,44,25)
GPS decimal degrees equivalent- N69.4764; W147.7403
Sample Numbers: DH97-98 to DH97-100

From here we flew back to Kavik with the clouds trying to tell us that the weather was about to change once again. At camp Steve Winfield was packing his possessions to leave with Walt Audi to start a new life in Kaktovik, at the end of the world.

AUGUST 12, Tuesday

Back in the rain today, we returned to the “Navy” Section to try in fill in the gaps in the section by down-climbing the cliffs. We tried several death-defying approaches to the cliffs, but access was not possible. Again, the pilot was concerned for our safety. Today we watched several caribou go berserk trying to flee the mosquitoes.

“Navy” Section- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-43; GPS- N69,32.52; W146,49.32 (N69,32,31; W146,49,19)
GPS decimal degrees equivalent- N69.5419; W146.8219
Sample Number: DH97-101 and DH97-102

We failed to get down the cliffs, and then decided to set down on the gravel bar across the river from the cliffs and make photomosaics of the

inaccessible upper part of the section. The epsilon bedding was nicely exposed in the upper fluvial sandstones (Figure FS38).

We then flew south in the rain and entered the Ignek Valley to examine the Canning exposures at Hue Creek. The Canning in this area was mainly thin-bedded turbidites (Figure FS39). Unfortunately, the GPS unit in the helicopter stopped working at this point. The contact between the Canning Formation and the Hue Shale was interpreted in this area (Figure FS40).

Hue Creek- Canning Formation (Houseknecht and Schenk)

Locality 97-44; GPS- N69,34.17; W144,48.73 (N69,34,10; W145,48,44)
GPS decimal degrees equivalent- N69.5694; W145.8122
Sample Numbers: DH97-103 and DH97-104

Finally, we flew west past Kavik to a section of the Sagavanirktok Formation containing coals and several fluvial sandstones. We sampled for vitrinite and palynology.

Kavik West Section- Sagavanirktok Fm. (Houseknecht and Schenk)

Locality 97-45; GPS- not working; W1/2 sec. 5, T.3N., R.21E.
Sample Numbers: DH97-105, DH97-106, DH97-107

AUGUST 13, Wednesday

Today there was no flying due to weather, with a very low ceiling and blowing rain. We were stranded in Kavik Camp with several unhappy hunters who were trying to catch flights to various locations within the Brooks Range. We boxed up all samples and equipment for shipping tomorrow to Deadhorse.

AUGUST 14, Thursday

Today we left Kavik Camp at noon in heavy rain for Deadhorse via Cape Smythe Air, and then traveled to Anchorage via commercial airline. There was quite a commotion in Deadhorse as the towing of a drill rig offshore was being protested. Ironically, the well turned out to be a dry hole. There were no accidents in the field in 1997, and everyone returned home safely.

ACKNOWLEDGEMENTS

We want to sincerely thank Kenneth J. Bird, Chief of the ANWR Project, for having the vision to send a crowd of Alaskan semi-neophytes into the field to examine as much of the stratigraphy and structure as possible prior to assessing the oil and gas potential of the ANWR 1002 area. Many thanks to Harvey Heffernan and Don Garrett of the U.S. Fish and Wildlife Service for permission to conduct geologic investigations in the ANWR, and to the USFWS for permission to refuel at their depot in the suburbs of Kaktovik.

We utilized Kavik Camp as a base of helicopter operations during each field session. Kavik Camp is operated by Mike Tolbert of Taiga Ventures in Fairbanks. Kavik Camp was managed by Sami Superdock, an amazing person who made life easy for all of us as we attempted to cope with field conditions. We flew into Kavik Camp from Deadhorse with 40-Mile Air in 1995, and with Cape Smythe Air in 1996 and 1997. Thanks to pilots David Duke, Rick, Gerry Moriarity, Maryann Waad, and Kermit Karns. Special thanks to Jim Spraggins, helicopter pilot for Air Logistics in 1996 and 1997, and Craig Wade, helicopter pilot for Trans-Alaska in 1997. Arrangements for helicopters and fixed-wing aircraft were made through our Office of Aircraft Services, and we appreciate all the efforts of J. Adrian Bennett and Lark Wuerth. We also thank Bill Hotchkiss, Chuck Blome, and Wayne Martin of the USGS Firearms Safety Class for teaching some of us the fundamentals of firearm safety.

In our field investigations we followed in the footsteps of many others, mainly from the Alaska Division of Geological and Geophysical Surveys, the University of Alaska-Fairbanks, and many oil company geologists who have crawled all over ANWR and the surrounding areas. Special thanks to Gil Mull, our mentor on many occasions, Naresh Kumar, formerly of ARCO and now with Growth Oil and Gas, Dallas, and John Decker of ARCO Alaska (now with ARCO Indonesia).

Figure FS1: Low altitude air photograph of Kavik Camp, located on the east bank of the Kavik River approximately 70 miles southeast of Deadhorse. Kavik has an airstrip and refueling facility that allows it to be used as a staging area for helicopter and fixed-wing flights to the Brooks Range (photograph by R.C. Burruss, August, 1996).

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Figure FS2: Paleocene clinoforms exposed along the west bank of the Canning River were examined as analogs for much of the seismic data in the Brookian section of the 1002 area. This view (looking west) shows thin bedded turbidites and mudstones overlying a large slump feature that appears structureless (photograph by K.I. Takahashi, August 5, 1995).

Figure FS3: View of the upper part of the Ledge Sandstone of the Ivishak Formation and the Kemik Sandstone along the west bank of the East Fork of Marsh Creek. This is one of the important localities to view the Lower Cretaceous unconformity (LCU), which separates the Kemik Sandstone (above) from the Ledge Sandstone (below), and documents significant erosion at the LCU in this area. D. Houseknecht is pointing to the LCU (photograph by C.J. Schenk, August 6, 1995).

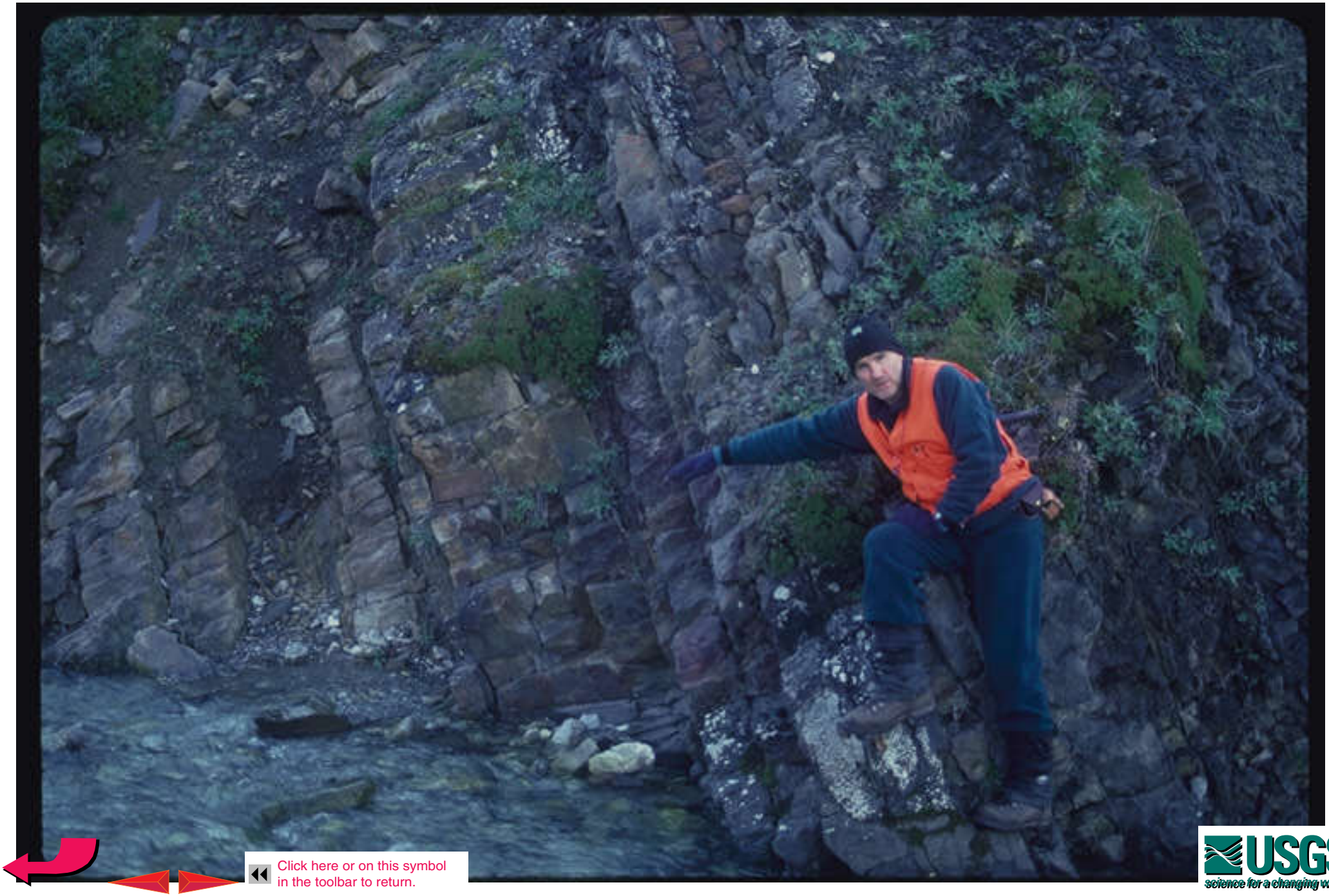

Figure FS4: View to the west of near vertical, coarse-grained fluvial channel sandstones of the Sagavanirktok Formation in the Kavik Hills area south of Kavik Camp. These sandstones were not oil-stained, but others in the area were oil stained (photograph by K.I. Takahashi, August 7, 1995).

Figure FS5: View to the east in Fire Creek Canyon illustrating the Fire Creek Siltstone Member of the Ivishak Formation. The Fire Creek Siltstone in this outcrop comprised several shallow marine to shelf parasequences with swaley and hummocky beds. The upper unit of the Fire Creek Siltstone is a tidal deposit that is overlain by the Shublik Formation (photograph by C.J. Schenk, August 8, 1995).

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Figure FS6: Low altitude air photograph of the type section of the Hue Shale at Hue Creek in the Ignek Valley. This view to the northwest shows the shales and bentonites of the Hue Shale, and the typical orange-red hue that forms on outcrops of the Hue Shale, and the typical deformation of the Hue (photograph by K.I. Takahashi, August 8, 1995).

Figure FS7: Gary Solin and Bronwen Wang sampling waters of Red Hill Spring on the west end of the Sadlerochit Mountains for baseline geochemistry (photograph by R.C. Burruss, July 31, 1996).

Figure FS8: View looking south of the oil stained fluvial channel sandstones of the Sagavanirktok Formation ("Stonehenge") near Kavik Camp. Inset photograph illustrates the oil-bearing sandstone on a fresh surface (photograph by R.C. Burruss, July 31, 1996).

Figure FS9: Shelley Orth examining the oil-bearing Paleocene fluvial sandstones at the top of the "Navy" section (photograph by R.C. Burruss, August 3, 1996).

Figure FS10: Natural gas bubbling up through the sediment along the margin of the Hulahula River. These waters were also sampled for baseline geochemistry (photograph by R.C. Burruss, August 3, 1996).

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Figure FS11: Low altitude air photograph of the Last Creek Section looking to the north. Prominent white band in middle of the exposure is the Kemik Sandstone (photograph by D.W. Houseknecht, August 6, 1996).

Figure FS12: View of the Kemik Sandstone and the overlying Pebble Shale Unit at Sadlerochit River #1 section. The Kemik Sandstone comprises several parasequences with hummocky and bioturbated sandstone. The Pebble Shale Unit displays several of its characteristic ironstone beds. Naresh Kumar for scale (photograph by C.J. Schenk, August 7, 1996).

Figure FS13: Low altitude air photograph looking south towards the Shublik Mountains from the central part of the Ignek Valley showing the prominent "Horseshoe" of the Kemik Sandstone, and "Bear Ridge" to the right of the "Horseshoe". The deformed orange-red Hue Shale is present in the interior of the syncline (photograph by C.J. Schenk, August, 1996).

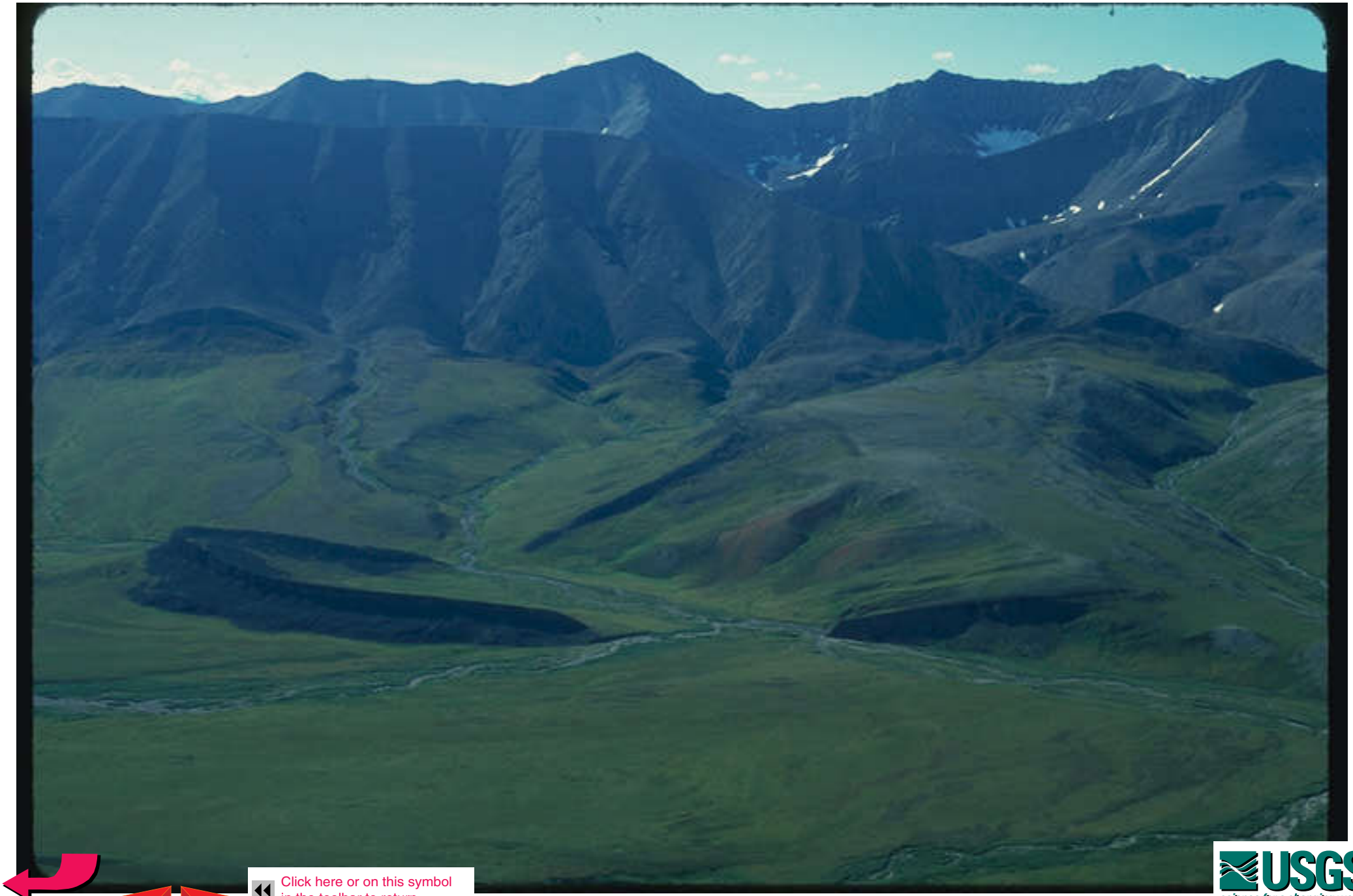

Figure FS14: View of the Kemik Sandstone and the Kingak Shale at the "Vertical Kemik" section. The Kingak Shale on the right contains several ironstone beds. The Kingak is separated from the Kemik by the Lower Cretaceous unconformity. D. Houseknecht for scale (photograph by C.J. Schenk, August 8, 1996).

Figure FS15: View of the Kemik Sandstone at Echooka Point on the Echooka River. D. Houseknecht is resting on the contact between the "Ignek Valley facies" of the Kemik Sandstone (above) and a finer grained member of the Kemik (below) that is only present at this locality. Compare with the Kemik Sandstone in the previous figure (photograph by C.J. Schenk, August 10, 1996).

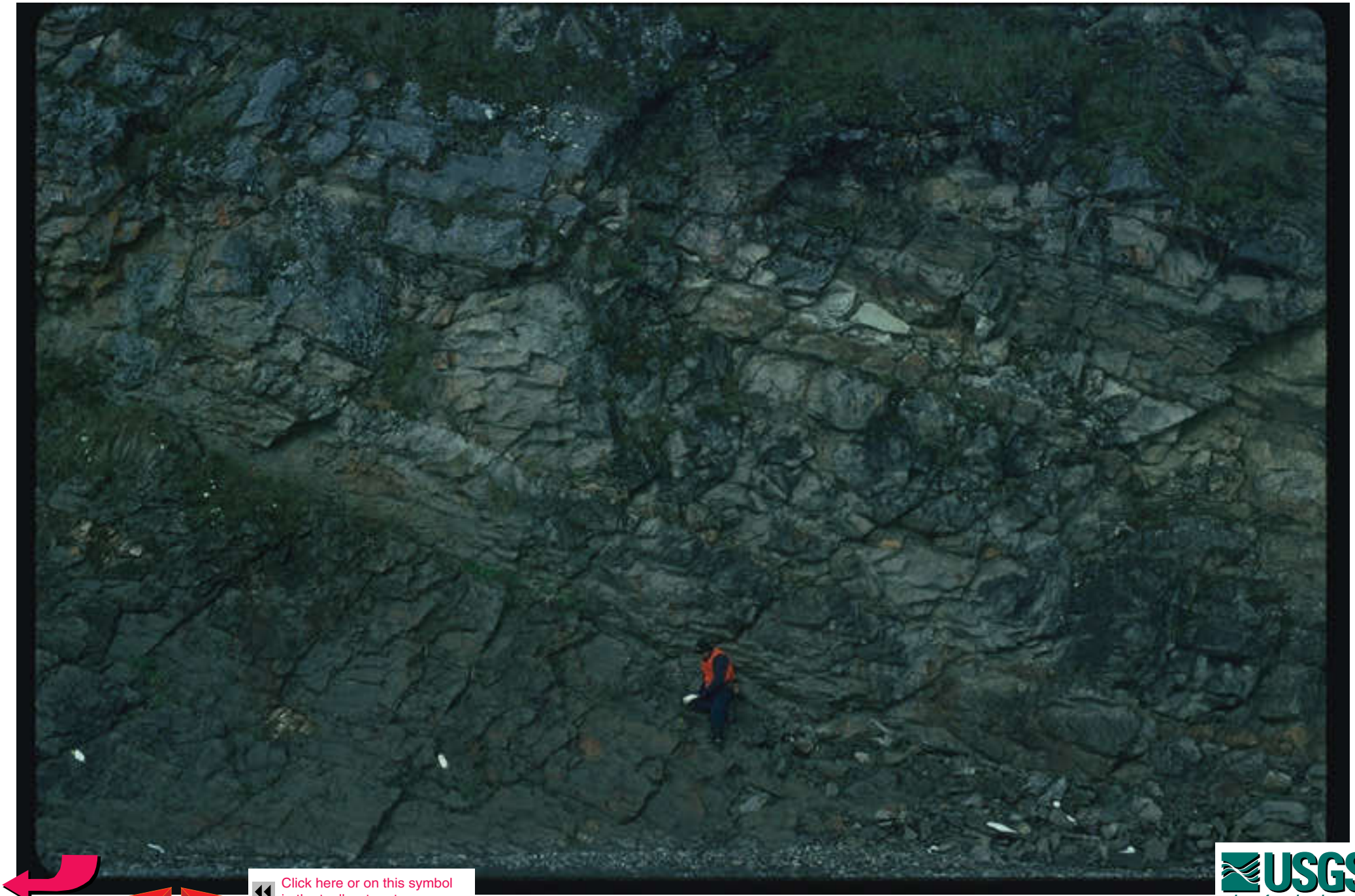

Figure FS16: View of the upper part of the Kemik Sandstone and the overlying Pebble Shale Unit at the Sadlerochit Spring section. The Pebble Shale Unit at this locality contains several ironstones and thin sandstones, reflecting a gradational contact between the Kemik and the Pebble Shale Unit. D. Houseknecht for scale (photograph by C.J. Schenk, August 11, 1996).

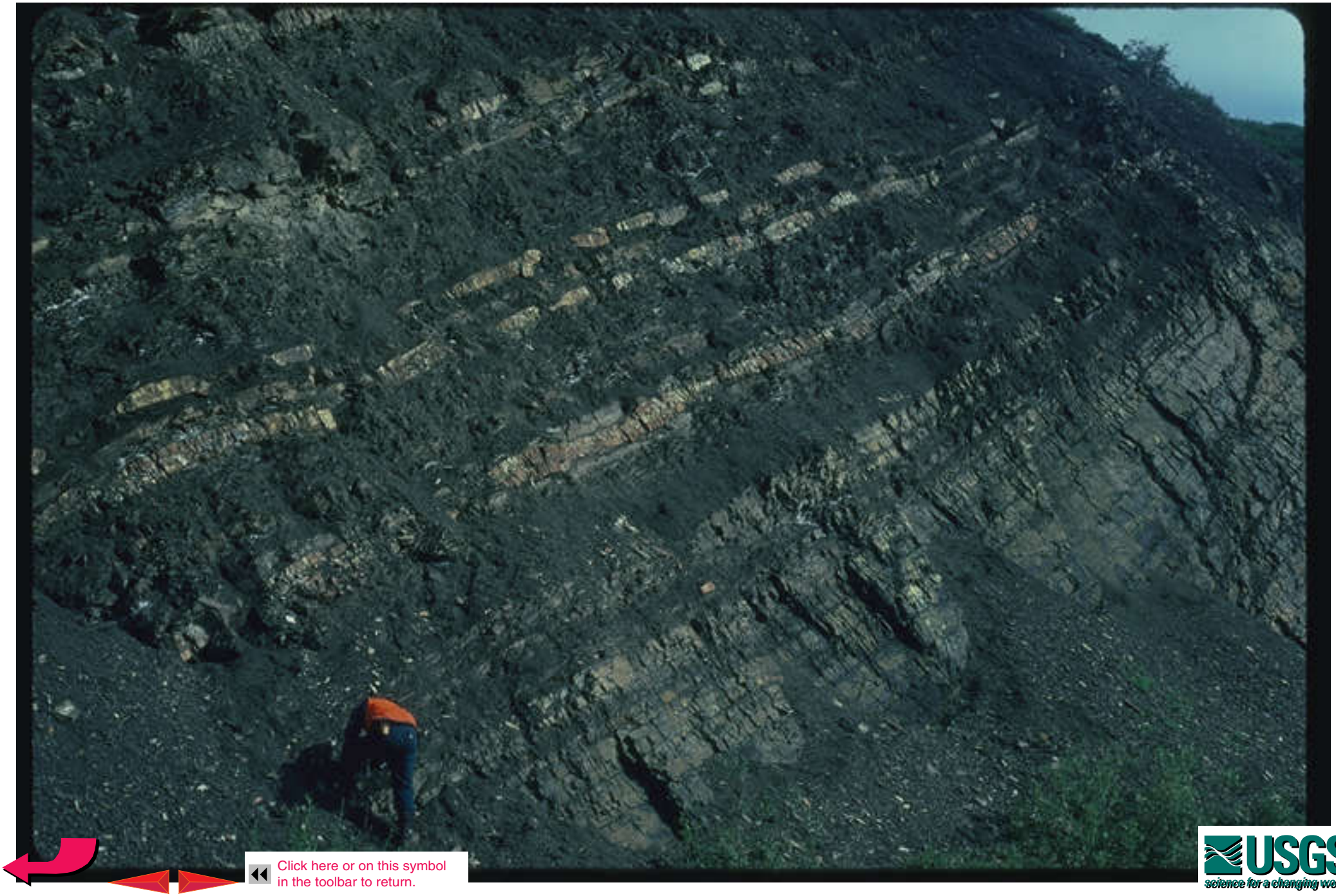

Figure FS17: View to the east showing the upper part of the Kingak Shale and the base of the Kemik Sandstone at the "Wolverine" section along the East Fork of Marsh Creek. The LCU is present between the Kingak and the Kemik. This is one of the best exposures of the Kingak Shale. The Kemik contains several shallow marine parasequences and ironstone bands that are common in this area (photograph by D.W. Houseknecht, August 11, 1996).

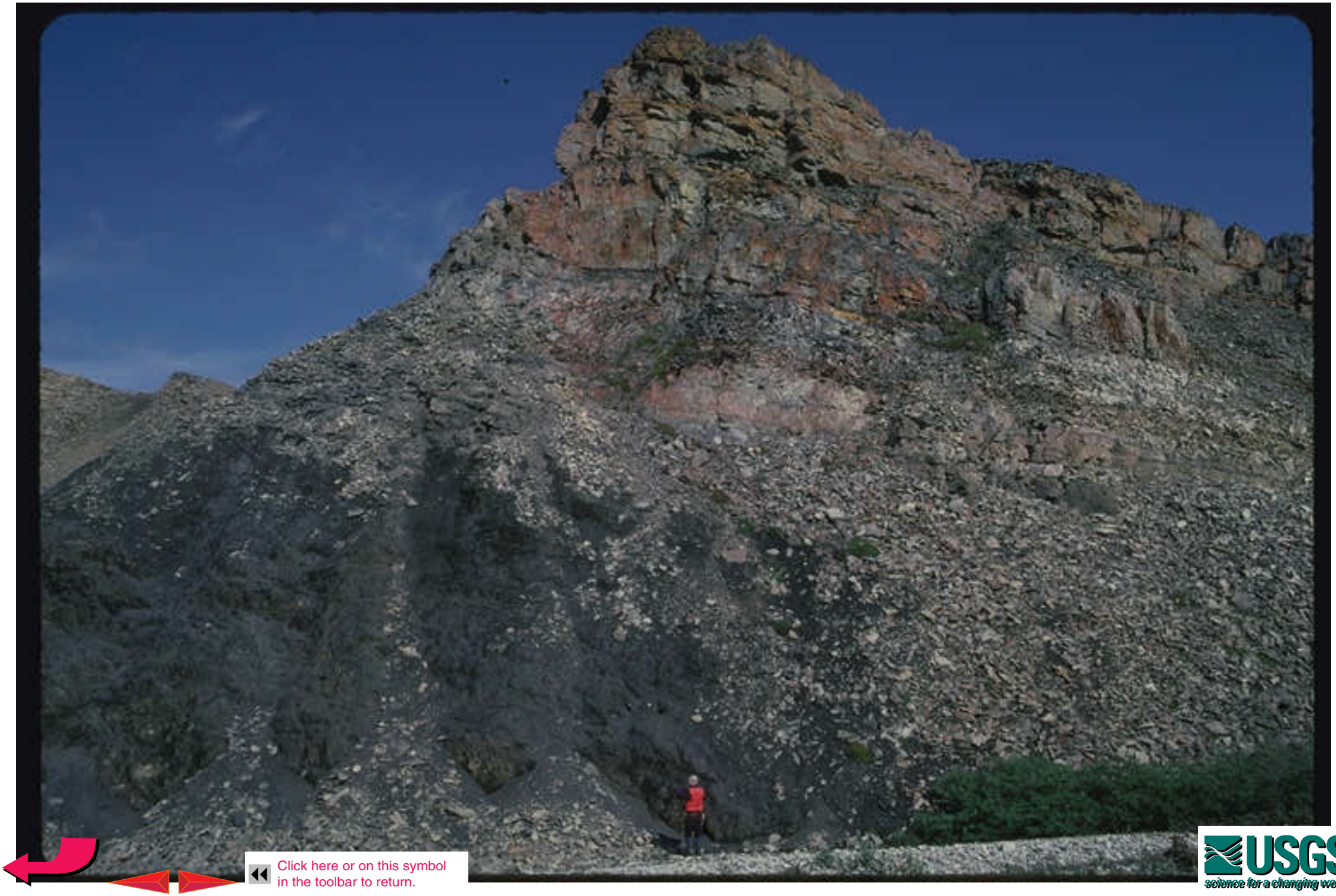

Figure FS18: Low altitude air photograph looking west showing recumbently folded Paleocene sandstones and mudstones at the bluff near Jago/Bitty (photograph by C.J. Schenk, August 12, 1996).

Figure FS19: View of the conglomerates of the Paleocene Sabbath Creek facies along the Jago River. Note that the geologist is wearing a bug jacket in a futile attempt to ward off the legions of mosquitoes (photograph by D.W. Houseknecht, August 12, 1996).

Figure FS20: View to the southeast of the surface expression of the Marsh Creek Anticline from the coast of the Beaufort Sea. Brooks Range is in the background (photograph by D.H. Houseknecht, August 12, 1996).

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Figure FS21: View of the "Marsh Creek facies" of the Kemik along the east bank of the West Fork of Marsh Creek on the north flank of the Sadlerochit Mountains. This facies of the Kemik overlies the Ledge Sandstone at this locality. Prominent ironstone bed is 1.5 feet thick (photograph by C.J. Schenk, August 13, 1996).

Figure FS22: View to the west of the south-dipping Ivishak Formation (gray-black) overlying the Lisburne Group and Katakturuk carbonates at the head of Katakturuk Canyon in the Ignek Valley. The Kemik Sandstone is seen as a thin band running the length of the Ignek Valley (photograph by D.H. Houseknecht, August 13,1996).

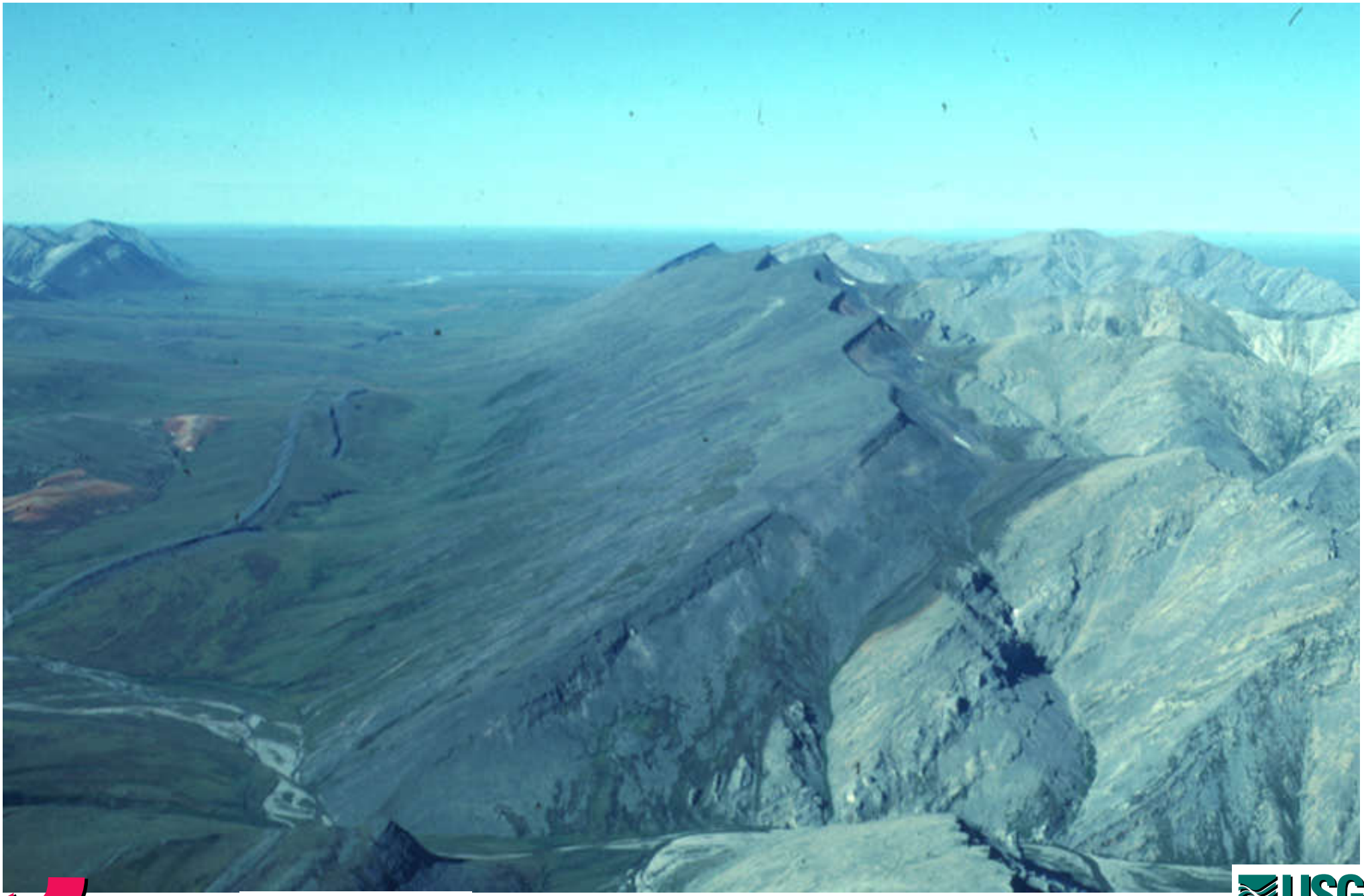

Figure FS23: Oil-stained sandstones along the crest of the Marsh Creek Anticline. Gil Mull appears to be coping well with field conditions (photograph by K. I. Takahashi, August 5, 1995).

Figure FS24: Low altitude air photograph of the "christmas tree" on the Sourdough #3 well near the western boundary of ANWR, drilled in 1994. Note the typical polygonal patterns on the tundra (photograph by R.C. Burruss, July 7, 1997).

Figure FS25: Deformed Kingak Shale along the Aichilik River, with Bob Burruss and Chris Potter for scale (photograph by T.E. Moore, July 11, 1997).

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Figure FS26: View to the north showing oil-bearing sandstones on the beach at Angun Point along the eastern coast of ANWR. Inset photograph shows a closer view of the oil-bearing sandstones (photograph by R.C. Burruss, July 11, 1997).

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Figure FS27: View to the east showing Paleocene sandstones and mudstones of the Canning Formation exposed along the Canning River at the "Kermit Island" section. The sandstones are thin-bedded and channel turbidites (photograph by C.J. Schenk, August 4, 1997).

Figure FS28: View of Canning Formation clinoforms exposed in the Kermit 2 section. Note the large low-angle truncation in the middle of the outcrop (photograph by D.W. Houseknecht, August 5, 1997).

Figure FS29: View to the east showing deformed Hue Shale along the east bank of the Canning River (photograph by D.W. Houseknecht, August 6, 1997).

Figure FS30: View to the north of sandstones and mudstones of the Sagavanirktok Formation exposed along the east bank of the Canning River at the "Navy" section. The Canning River was up against this bank, making the section difficult to measure (photograph by C.J. Schenk, August 6, 1997).

Figure FS31: Preparing to use the USGS "navy" to measure a section of the Sagavanirktok Formation along the east bank of the Canning River at the "Navy"section. From left to right- Craig Wade (pilot), D. Houseknecht, and M. Pawlewicz (photograph by C.J. Schenk, August 7, 1997).

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Figure FS32: View of sandstones of the Sagavanirktok Formation exposed at the confluence of the Katakturuk River (photograph by D.W. Houseknecht, August 10,1997).

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Figure FS33: View looking north of the thin-bedded turbidites of the Paleocene Canning Formation along the Katakturuk River. Low-angle truncations of turbidite units are common in this outcrop. D. Houseknecht for scale (photograph by C.J. Schenk, August 10, 1997).

Figure FS34: View to the north of the thin-bedded turbidites of the Canning Formation exposed along the East Fork of the Tamyariak River (photograph by D.W. Houseknecht, August 10, 1997).

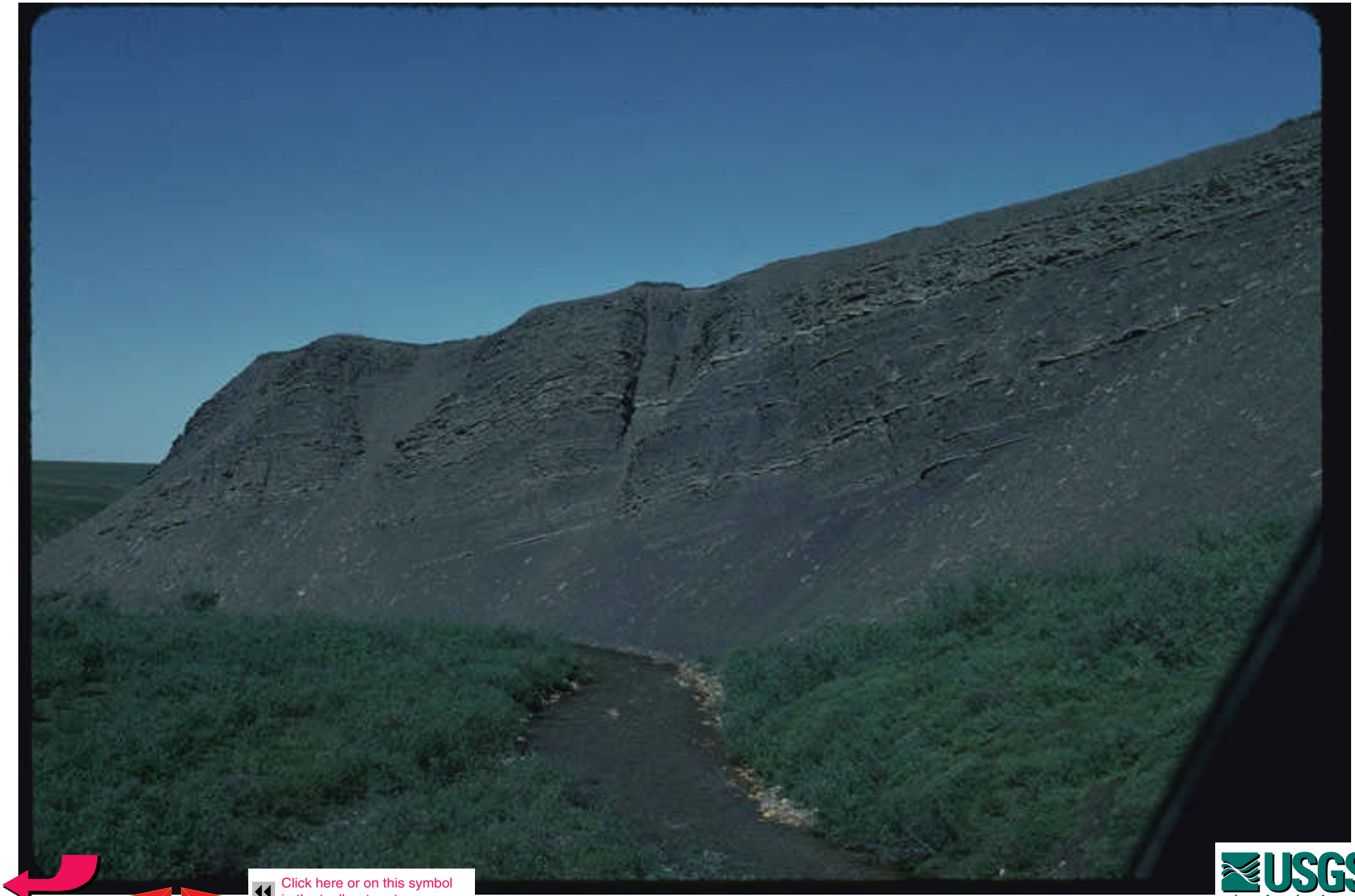

Figure FS35: Low altitude air photograph of Sagwon Bluffs along the Sagavanirktok River, looking northwest, showing the thick fluvial sandstones (photograph by D.W. Houseknecht, August 11, 1997).

Figure FS36: View to the north of D. Houseknecht sampling the uppermost coal bed at Sagwon Bluffs along the west side of the Sagavanirktok River. Cliffs in the background are fluvial conglomerates (photograph by C.J. Schenk, August 11, 1997).

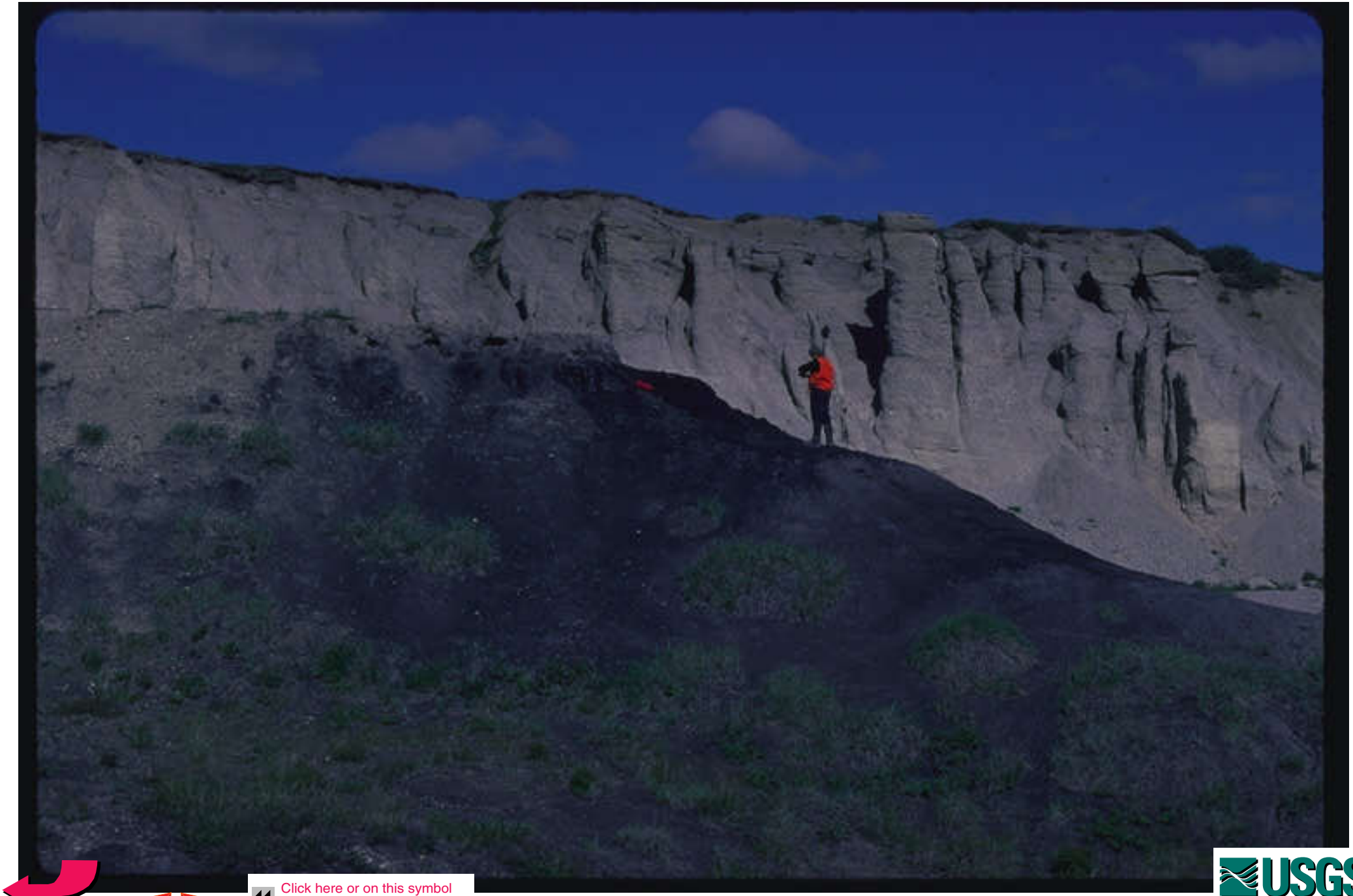

Figure FS37: View of conglomeratic Paleocene fluvial sandstones of the Sagavanirktok Formation at the "Seismic River" section. These deposits were classic braided fluvial deposits (photograph by D.W. Houseknecht, August 11, 1997).

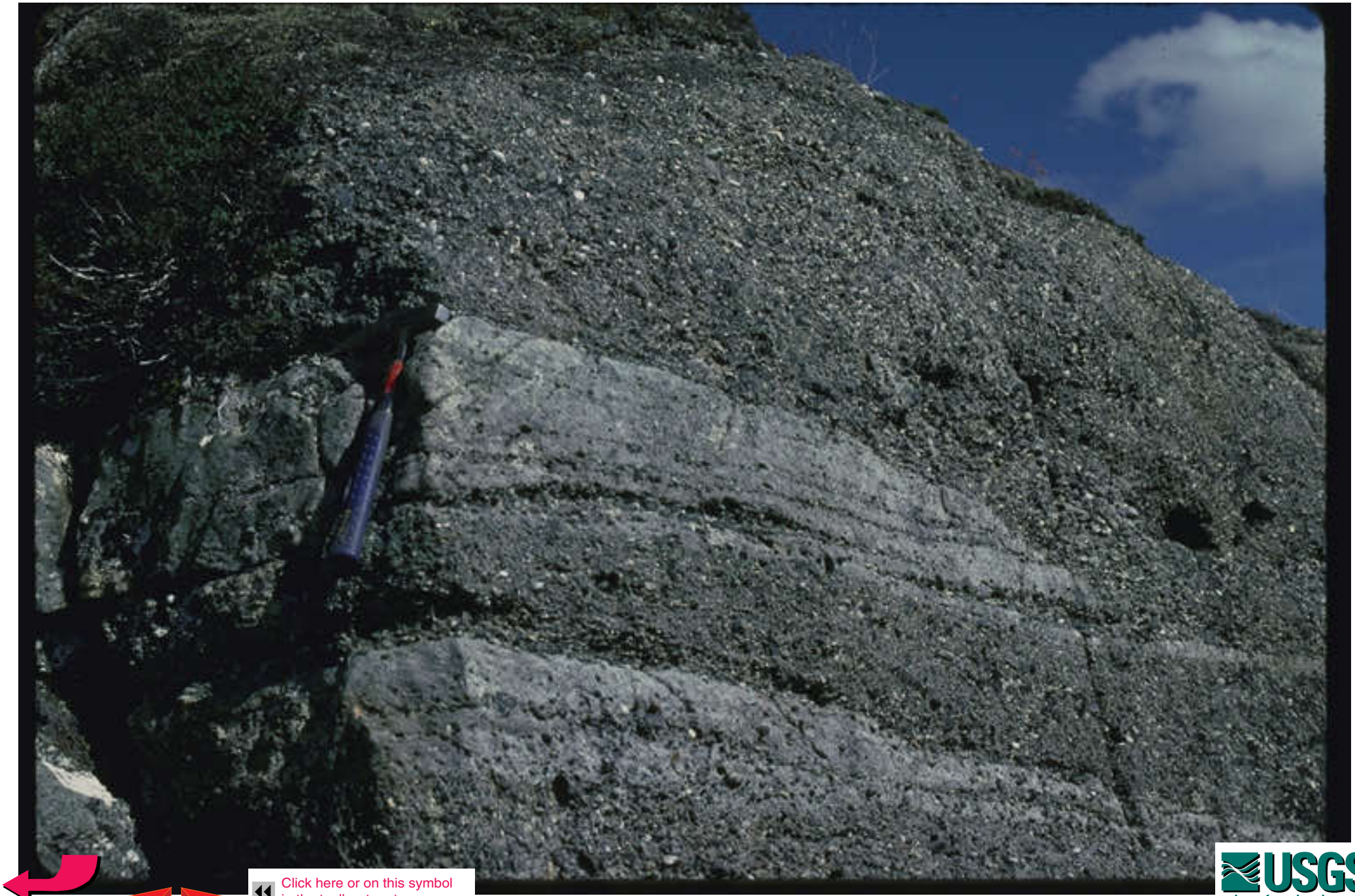

Figure FS38: View looking to the east of epsilon-bedded fluvial sandstones in the Sagavanirktok Formation in the upper part of the "Navy" section. Prominent bed sloping to the river at the left is about 7 feet thick (photograph by C.J. Schenk, August 12, 1997).

Figure FS39: View to the south of thin-bedded turbidites in the Paleocene Canning Formation at Hue Creek in the Ignek Valley. About 60 feet of section is exposed in this view (photograph by C.J. Schenk, August 12, 1997).

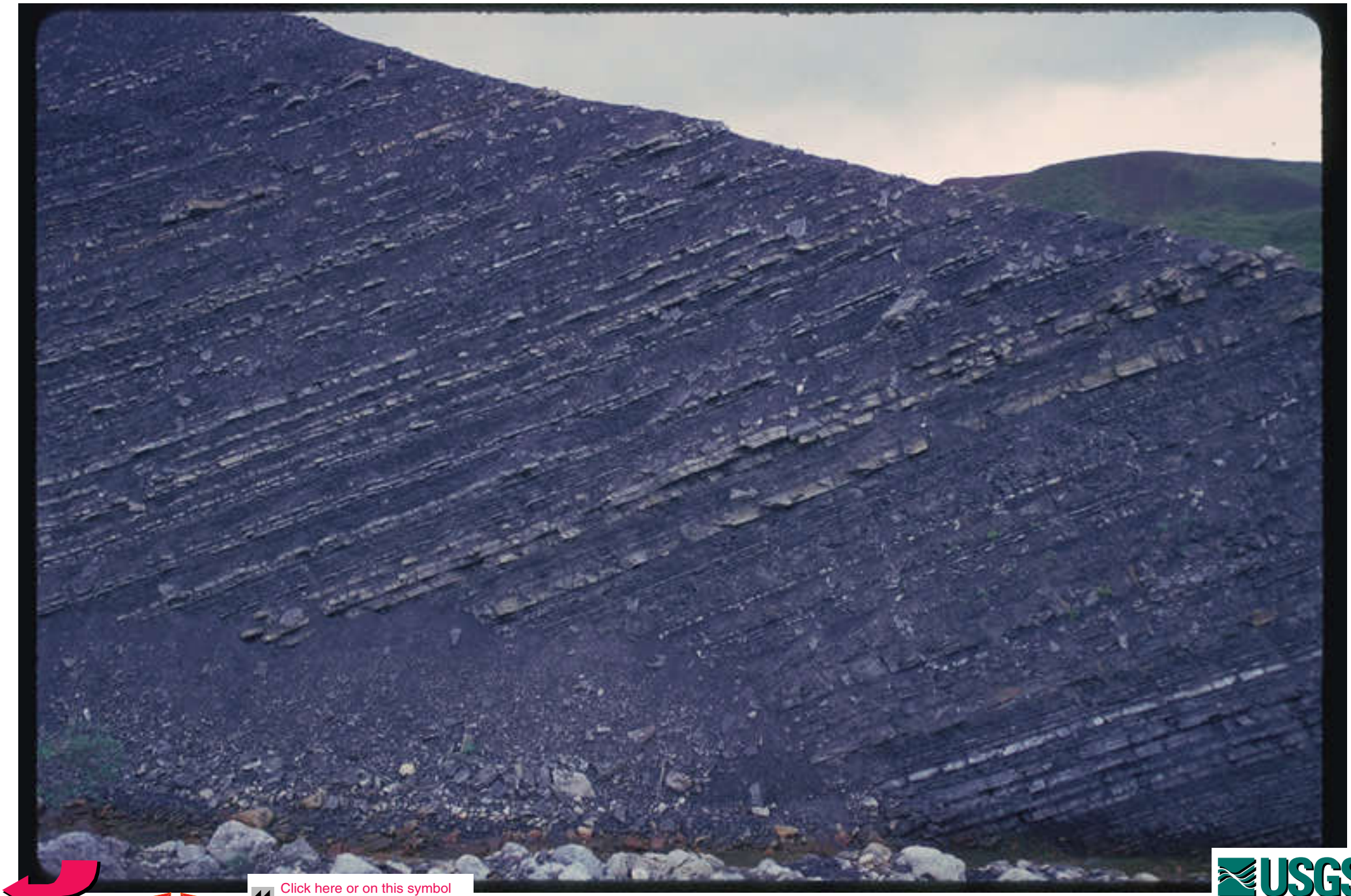

Figure FS40: Contact (at hammer) between the Canning Formation and the Hue Shale in overturned beds along Hue Creek (photograph by D.W. Houseknecht, August 12, 1997).

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

OPEN-FILE REPORT 98-34
PLATE FS1

EXPLANATION

- 97-41 Field locality (year-site)
- Boundary of the Arctic National Wildlife Refuge
- Boundary of the assessment area (Section 1002) of the Alaska National Interest Lands Conservation Act (ANILCA)
- Boundary of the Kaktovik Inupiat Corporation

Assessment area (Section 1002) of the Alaska National Interest Lands Conservation Act

ARCTIC NATIONAL WILDLIFE REFUGE

Universal Transverse Mercator Projection

SCALE 1: 250 000

5 0 5 20 MILES

5 0 5 20 25 30 KILOMETERS

Geology from Geologic Map Of The Demarcation Point, Mt. Michelson, Flaxman Island, And Barter Island Quadrangles, Northeastern Alaska, by Heather A. Marshall, Michael S. Sinor, and Kenneth J. Bird

MAP SHOWING U.S.G.S FIELD LOCALITIES (1995-1997)

Compiled by
Michael S. Sinor

1998