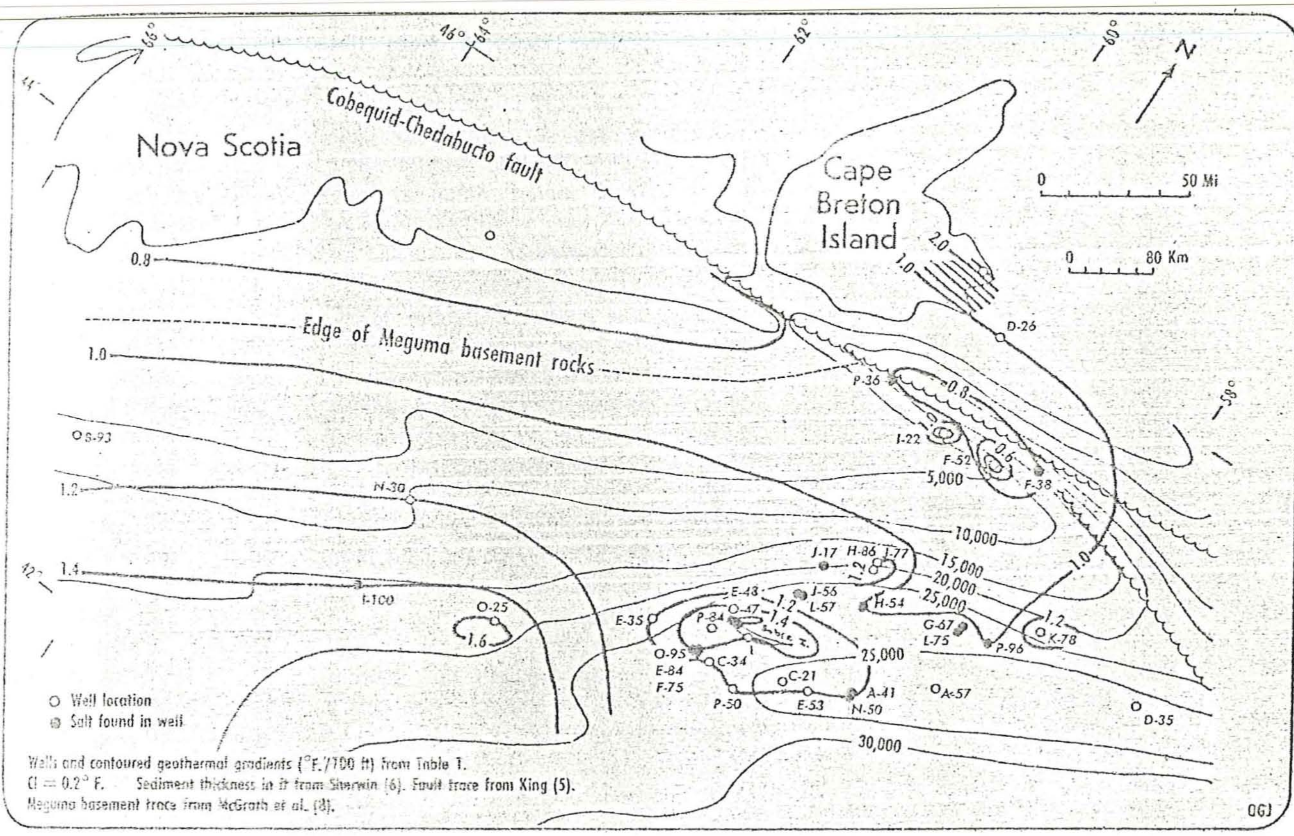
Fig. 1



Wells and contoured geothermal gradients (°F./100 ft) from Table 1. CI = 0.2° F. Sediment thickness in ft from Sherwin (6). Fault trace from King (5). Meguma basement trace from McGrath et al. (8).

Geothermal gradients help predict petroleum potential of Scotian Shelf

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SUBSURFACE temperature is a useful parameter in predicting whether an area has petroleum potential.

Other indications are the presence of source and reservoir beds and effective migration and trapping mechanisms. In this paper, the authors examine temperature data from the only wells drilled on the Atlantic Outer Continental Shelf (AOCS) — those on the Canadian Scotian Shelf.

The data presented here are from 45 Shell Oil Co. and Mobil Oil Corp. wells (Fig. 1) and were released by those companies.

On the basis of velocity correlations, the USGS AOCS project[1] has suggested that the stratigraphy and lithology of Georges Bank basin and the Scotian Shelf are similar. Thus, the geothermal data presented may aid in petroleum-resource evaluation of the Georges Bank area.

The offshore data were taken directly from drilling logs where temperatures were recorded at various intervals in the wells from 1 to 48 hr after cessation of drilling-mud circulation. Whether this technique for adequately measuring geothermal temperature is valid can be debated, although errors may be no greater than 10% when wells are not permitted to come to thermal equilibrium.[2]

All temperature measurements were plotted against depth; these are shown in Fig. 2. All values are corrected to depth below sea level.

To calculate geothermal gradients, temperature readings were averaged from the sonic, density, electrical, and radioactivity logs. Each well had an average of four temperature readings which were available for study.

A linear regression was computed using all available points (Fig. 2), and the result shows a roughly linear increase in temperature with depth. The average thermal gradient of wells on the Scotian Shelf is calculated to be 1.2° F./100 ft (2.2° C./100 m) with a correlation coefficient (r) of 0.97.

The geothermal gradient of individual wells (Table 1) was determined by subtracting the uppermost temperature measurement from the bottom-hole measurement and dividing by the difference in depths.

The authors used measurements taken in the hole itself rather than mean surface temperature because an average mean temperature does not take the actual month-of-the-year value into account. Top measurements were taken at an average

Table 1

Approximate geothermal gradients

	°F./100 ft
Abenaki J-56	1.0
Abenaki L-57	1.2
Argo F-38	.8
Chippewa G-67	1.2
Chippewa L-75	1.0
Cree E-35	1.2
Crow F-52	.3
Dauntless D-35	1.1
Eagle C-21	1.3
Erie D-26	1.0
Esperanto K-78	1.3
Eurydice P-36	.8
Fox I-22	1.4
Huron P-96	1.1
Iroquois J-17	1.1
Marmora C-34	1.2
Mic Mac J-77	1.2
Mic Mac H-86	1.2
Missisauga H-54	1.0
Mohawk B-93	1.1
Mohican I-100	1.4
Naskapi N-30	1.2
Onondaga E-84	1.4
Onondaga O-95	1.4
Onondaga F-75	1.2
Oneida O-25	1.6
Primrose A-41 & 1a-41	1.2
Primrose N-50	1.2
Sable Is #1	1.4
Sable Is E-48	1.6
Sable Tetco O-47	1.6
Sauk A-57	1.1
Thebaud P-84	1.5
Triumph P-50	1.2
Wyandot E-53	1.2

Table 2

Comparisons*

	°F./100 ft
West Texas	0.7
Texas Panhandle	.7
Southern North Sea	1.2
Scotian Shelf (this paper)	1.2
North Texas	1.4
South Texas	1.8
East Texas	2.0
Texas Gulf Coast	2.6

*Average geothermal gradients from selected localities. (From 2, 3, and 4, except as noted.)

depth of about 2,600 ft (800 m) to eliminate the problem of erratic values in the first few hundred meters of a hole.

A general comparison of the Scotian Shelf average geothermal gradient with those of a few other analogous productive areas (Table 2) shows that this average gradient is not unusual. For example, the values fall near those reported from the southern North Sea,[2] which has an equivalent near-surface temperature.

Southern Texas, another clastic sediment province like the Scotian Shelf but having a higher mean surface temperature, has a higher average geothermal gradient.[3]

A geothermal-gradient contour map (Fig. 1) was plotted using the calculated geothermal gradients for individual wells. Gradients from two onshore wells are from unpublished data provided by the AAPG Geothermal Survey of North America (GSNA).

Where more than one well was drilled on a structure, as on the Onondaga (E-84, F-75, O-95) and Mic Mac (J-77, H-86) anticlines, gradients were averaged (Fig. 1).

The Scotian Shelf in this area contains a broad trough, the Scotian basin. The basin is filled with 30,000 ft (9 km) of Tertiary, Cretaceous, and Jurassic clastic rocks[5] and less than 10% carbonate rocks in the total drilled section. Most of the area is presumably underlain by thick deposits of salt.[6]

A comparison of temperature anomalies with geological and geophysical features shows that the distribution of thermal anomalies reflects major sedimentary and structural elements. Geothermal highs occur over positive structural elements. The broad northeast trend is parallel to the edge of Meguma basement rocks and the Continental Shelf.

A thermal low, the northernmost anomaly at F-52, follows the trace of the Cobequid-Chedabucto fault and the negative Orpheus gravity anomaly.[7] The thermal high that appears to butt against this low centers over the Fox (I-22) anticlinal structure.

Here metamorphic basement comes within 2,700 ft (820 m) of the surface and would be expected to have a higher thermal conductivity than do the surrounding sediments.

An interesting thermal high coincides with the Sable Island (O-47, E-48) diapiric structure. The high is close to both the deepest part of the Scotian basin and the trace of a positive Bouguer gravity anomaly.[7]

The high may possibly be related to nearby Triassic intrusive (?) bodies. However, the Erie (D-26) was drilled near a Triassic intrusive (?) body and an average gradient was mea sured.

The southwest anomaly at the One da (O-25), a thermal high, appears t close on the map. It may, however be just part of the general trend c higher values toward the edge of th Continental Shelf. This general tren of higher values appears to includ the Mohican (I-100) salt diapir wit which it may be associated.

However, there does not appear t be any consistent relationship be tween temperature highs and sal domes, which might be expecte because of the high thermal conductiv ity of salt. Values over the Primros (A-41, N-50), Huron (P-96), Abenak (J-56, L-57), and Chippewa (G-67, L 75) salt structures are average whereas the Sable (E-48, O-47), Onon daga (E-48, F-75, O-95), and Mohica (I-100) diapirs have high values.

Values over the two salt structure in the trace of the Cobequid-Cheda bucto fault — Eurydice (P-36) an Argo (F-38) — are low.

The limiting lower isotherm of hy drocarbon generation [150° F. (6 C.)] forming the liquid window di cussed by Pusey,[9] is reached (Fig. 2 at about 7,800 ft (2,400 m) in the Sco tian Shelf wells. Optimum tempera tures for petroleum occurrence mig be expected at about 200° F. (9 C.),[10] which is reached at 12,000 (3,600 m).

The deepest well drilled, Sable I land No. 1, reached 250° F. (121 C.) at 15,000 ft (4,600 m). A linear e trapolation to 300° F. (149° C shown by the dashed extention of th best-fit line in Fig. 2 indicates that th approximate upper limit of comme cial crude-oil accumulation would co relate with a sediment depth of abo 20,000 ft (6,000 m).

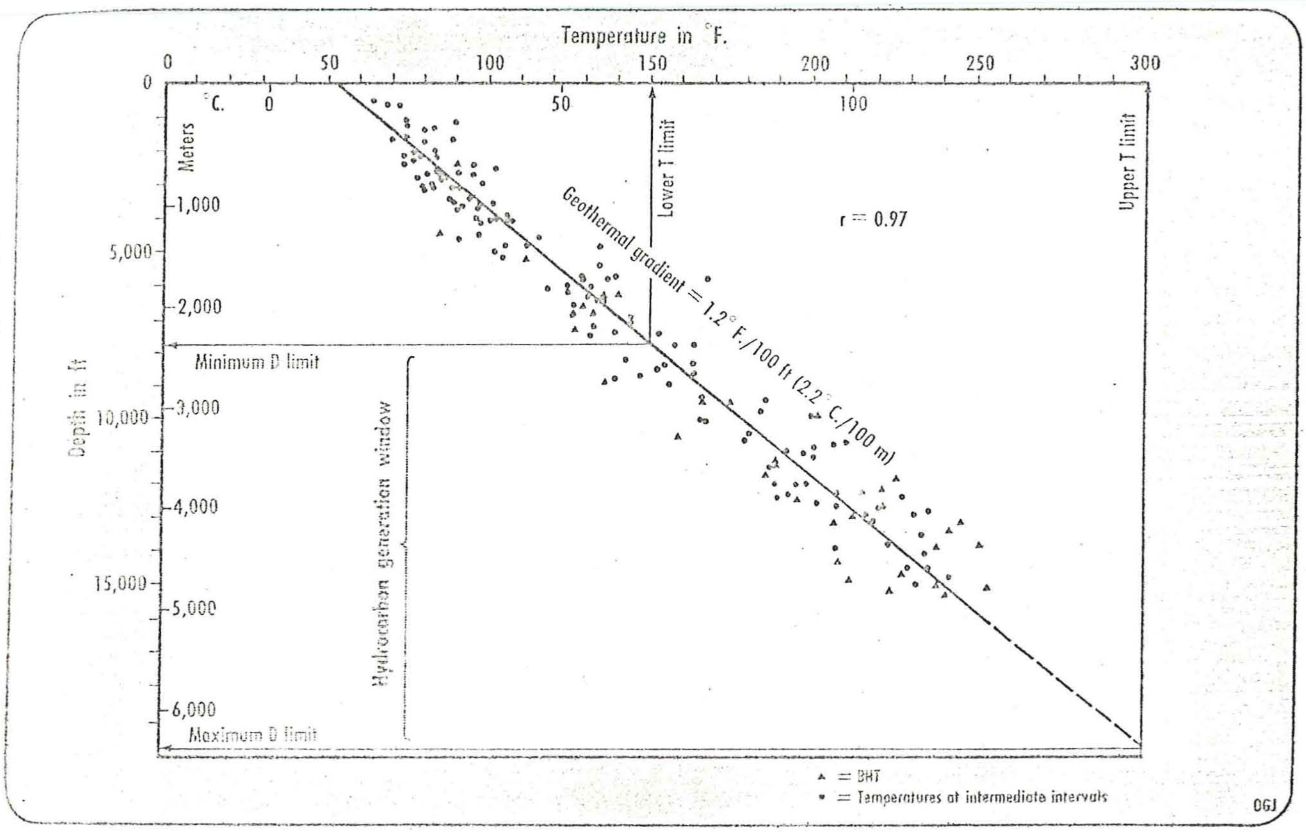
As such, the liquid window coul include about 12,000 ft (roughly 3,7 m) of sediments beneath the Scotia Shelf — that is between depths 8,000 and 20,000 ft.

Jurassic to Holocene thicknesses Georges Bank basin reach a ma mum of 26,000 ft (7,800 m).[1] If Georg Bank basin has the same or simil geothermal gradients as those of t Scotian Shelf, the sedimentary secti of the basin will fully accommoda a similar commercial hydrocarb liquid window.

Assuming no previous change in ge thermal history, hydrocarbons m

Fig. 2

Depth-temperature relations for Scotian Shelf wells



have been generated and may exist in commercial quantities in Georges Bank basin in sediments essentially ranging in age from the Jurassic to Upper Cretaceous as determined by our ongoing seismic-reflection studies.

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Eddy County well flows Canyon oil

A CANYON oil discovery has been completed in South Eddy County, N.M.

Black River Corp., Midland, Tex., 3 Federal "BR," wildcat in 33-25s-24e, 8 miles southwest of White City in Southwest Eddy County, has been completed from Canyon perforations at 5,927-39 ft.

On 24-hr potential test, the well flowed 102 bbl of 42°-gravity oil through a ¼-in. choke with a GOR of 1,372:1 and tubing pressure of 300 psi. A drill-stem test from 5,920-70 ft, open 3 hr and 15 min, surfaced gas in 4 min and recovered 255 ft of heavily oil and gas-cut mud, 200 ft of mud-cut oil, and 5 ft of oil.

Well site is 1 mile southwest of Morrow gas and 1 mile northwest of Delaware oil production in the Washington Ranch field. There is no nearby Canyon production.

Northern Natural Gas Co. plans to drill an 11,400-ft Morrow wildcat in the county, 16 miles southeast of Lake Wood and 1½ miles northeast of an unnamed Cisco Canyon gas discovery. The new project is 1 McGruder-Hill unit, in 13-22s-25e.

The White City field of Eddy County has been expanded by Mesa Petroleum Co.'s 1 Ringer, 3-25s-26e, 3 miles southwest of Black River.

The White City, Morrow gas, field completion is 2½ miles southeast of nearest production in the field, and 1¾ miles southwest of Morrow gas production in the Crawford field. Producing from 11,098-11,448 ft, the well was completed for a calculated absolute open flow of 2.924 MMcfd of dry gas with a shut-in wellhead pressure of 3,595 psi.