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6. Data Report: Heavy Mineral Analysis of Miocene to Pleistocene Sediments (Holes 1071C, 1071F, 1072A, and 1073A)[1]

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INTRODUCTION

The purpose of this paper is to report the heavy mineral content of Miocene to Pleistocene sequences drilled during Ocean Drilling Program Leg 174A on the New Jersey Shelf. Sandy intervals recovered from Holes 1071A, 1071F, 1072A, and 1073A were sampled for heavy mineral analysis. Because of the low core recovery of the sandy parts of the succession, sampling has been incomplete. In spite of the resulting restriction and because of major variations in heavy mineral assemblages, eight distinct heavy mineral associations could be defined. The data presented thus considerably extend the present knowledge on the lithology of the stratigraphic record as described by Austin, Christie-Blick, Malone, et al. (1998). In this chapter the heavy mineral associations and their assignment to particular sequences are described.

METHOD OF ANALYSIS

A total of 67 samples were taken from sandy intervals of Holes 1071A, 1071F, 1072A, and 1073A. Of these a set of 50 samples contained enough sandy material for separating the heavy mineral suite. The sand fraction was separated from the silt and clay fractions by wet sieving through a 63-µm sieve. The remaining sand fraction was dried, and subsequently the 125- to 500-µm fraction was separated by dry sieving. Owing to the small sample quantities, heavy minerals were ex-

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tracted from the 125- to 500-µm sand fraction by gravity settling in bromoform with a specific gravity of 2.80. For the same reason, treatment with dilute HCl was rejected, and processing through a magnetic separator was not applied. For heavy mineral mounts the mounting medium Mountex (n = 1.67, where n = optical refraction index) was used.

The identification of heavy minerals was made optically using a polarizing microscope. Proportions of nonopaque detrital heavy minerals were estimated by counting a minimum of 200 grains by the ribbon method as described in Mange and Maurer (1991).

RESULTS

The nonopaque heavy minerals identified during the study are minerals of the amphibole group, andalusite, apatite, minerals of the epidote group, garnet, kyanite, monazite, minerals of the pyroxene group, rutile, sillimanite, staurolite, tourmaline, and zircon. Their abundances are given in Tables T1, T2, and T3. Comprehensive descriptions of mineralogical characteristics are given by Boenigk (1983), Mange and Maurer (1991), and Pichler and Schmitt-Riegraf (1993). Short descriptions of the most abundant varieties of the observed heavy minerals are listed in Table T4. Opaque grains, micas, and glauconite also present within the heavy mineral fraction were excluded from the count during the analysis, as is common practice.

T1. Results of heavy mineral analyses, Holes 1071C and 1071F, p. 8.

T2. Results of heavy mineral analyses, Hole 1072A, p. 9.

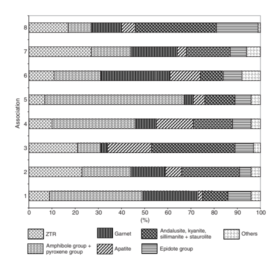
T3. Results of heavy mineral analyses, Hole 1073A, p. 10.

T4. Heavy minerals, Holes 1071A, 1071F, 1072A, and 1073A, p. 11.

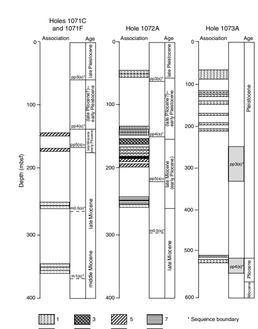
Heavy Mineral Associations

As Tables T1, T2, and T3 show, there are clear variations in heavy mineral assemblages in the shelf and slope sediments recovered. Particularly variable are the proportions of the ultrastable minerals zircon, tourmaline, and rutile (ZTR), garnet, the minerals of the amphibole group, and the minerals of the pyroxene group. These variations define eight distinct associations (Fig. F1), all of which are represented in the shelf sediments (Fig. F2). Within the slope sediments, however, only two associations (1 and 2) are present (Fig. F2).

F1. Composition of heavy mineral associations, p. 6.



F2. Distribution of heavy mineral associations, p. 7.



The following mineral associations were defined:

Association 1: Characterized by very low proportions of ZTR (mean = 9%), a high proportion of the unstable amphibole and pyroxene group (mean = 40%), and garnet (mean = 24%).

Association 2: Characterized by mean proportions of 23% ZTR, 21% amphiboles and pyroxenes, and 15% garnet.

Association 3: Characterized by mean proportions of 21% ZTR, a low proportion of amphiboles and pyroxenes (10%), and only 3% garnet.

Association 4: Characterized by low portions of ZTR (mean = 10%), a high proportion of amphiboles and pyroxenes (mean = 36%), and a low proportion of garnet (mean = 9%).

Association 5: Contains only 7% of ZTR but 60% of amphiboles and pyroxenes and only a 4% mean proportion of garnet.

Association 6: Represented by only one sample but exhibits a separate heavy mineral suite with mean proportions of 11% ZTR, 20% amphiboles and pyroxenes, and 30% garnet, the highest proportion.

Association 7: Characterized by mean proportions of 27% ZTR, 17% amphiboles and pyroxenes, and 20% garnet.
Association 8: Characterized by mean proportions of 14% ZTR, 10% amphiboles and pyroxenes, and by 13% garnet.

Heavy Mineral Associations of the Shelf Sequences

The Miocene to Pleistocene sedimentary sequence recovered on the shelf during Leg 174A (Sites 1071 and 1072) can be subdivided into at least four discontinuity-bounded sequences (Austin, Christie-Blick, Malone, et al., 1998). In the following the heavy mineral associations of each sequence are described (cf. Fig. F2). The sequences are named according to their basal bounding surface.

Heavy Mineral Associations of Sequence pp3(s)

Due to the low recovery, samples of late Pleistocene sequence pp3(s) could have been taken only from the sediments recovered from Hole 1072A. All heavy mineral assemblages belong to association 1, characterized by a low proportion of ZTR and a high proportion of the unstable amphibole and pyroxene group. The proportion of garnet is generally high, but the assemblages of the slope sediments especially exhibit quite reasonable fluctuations. There is no reason to assume changes in the source area. Therefore, these fluctuations are best explained by solution processes during weathering or early diagenesis (Grimm, 1973).

Heavy Mineral Associations of Sequence pp4(s)

Samples of sequence pp4(s) also could have been taken only from sediments recovered from Hole 1072A. The samples come from the basal part of sequence pp4(s) and belong to association 2.

Heavy Mineral Associations of Sequence m0.5(s)

Sediments of sequence m0.5(s) were sampled from cores of Holes 1071C, 1071F, and 1072A. The heavy mineral assemblages belong to a total of six associations. At Hole 1072A associations 3, 4, 5, and 6 are present in sediments deposited above surface pp5(s), which is interpreted as a flooding surface (Austin, Christie-Blick, Malone, et al., 1998). Noticeable is the decrease of the proportion of ZTR downsection and the concurrent increase of the proportion of the amphibole and pyroxene group. Of interest is the presence of association 6 in Hole 1072A. This association is represented by a single sample, derived from the sandy fill of a bioturbation feature. The host sediment is a homogeneous silty clay. The samples below and above, as well as the corresponding sample from Hole 1071C, exhibit a clearly different composition of heavy minerals and belong to association 5. This could be explained as follows: within the burrows of bioturbation fabrics sediments are preserved but are not recorded as discrete sedimentation units due to sediment bypass or erosion. Below the pp5(s) discontinuity, heavy mineral associations 7 and 8 are present at both sites.

Heavy Mineral Associations of Sequence m1(s)

Sediments of sequence m1(s) could have been sampled only from drilled cores at Hole 1071F. All samples belong to association 8.

Heavy Mineral Associations of the Slope Sequences

The sediments of the slope recovered in drilled cores from Hole 1073A are generally finer grained. Therefore only sediments of sequences pp3(s) and pp4(s) yield enough sandy material for separating heavy minerals. The slope sediments of sequence pp3(s) belong to heavy mineral association 1. Within sequence pp4(s), associations 1 and 2 are observed.

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REFERENCES

Austin, J.A., Jr., Christie-Blick, N., Malone, M.J., et al., 1998. *Proc. ODP, Init. Repts.,* 174A: College Station, TX (Ocean Drilling Program).

Boenigk, W., 1983. *Schwermineralanalyse:* Stuttgart (Ferdinand Enke Verlag).

Grimm, W. D., 1973. Stepwise heavy mineral weathering in the residual quartz gravel, Bavarian Molasse (Germany). *Contr. Sedimentology,* 1:103–125.

Mange, A.M., and Maurer, H.F.W., 1991. *Schwerminerale in Farbe:* Stuttgart (Ferdinand Enke Verlag).

Pichler, H., and Schmitt-Riegraf, C., 1993. *Gesteinsbildende Minerale im Dünnschliff:* Stuttgart (Ferdinand Enke Verlag).

Figure F1. Composition of heavy mineral associations. ZTR = zircon, tourmaline, rutile.

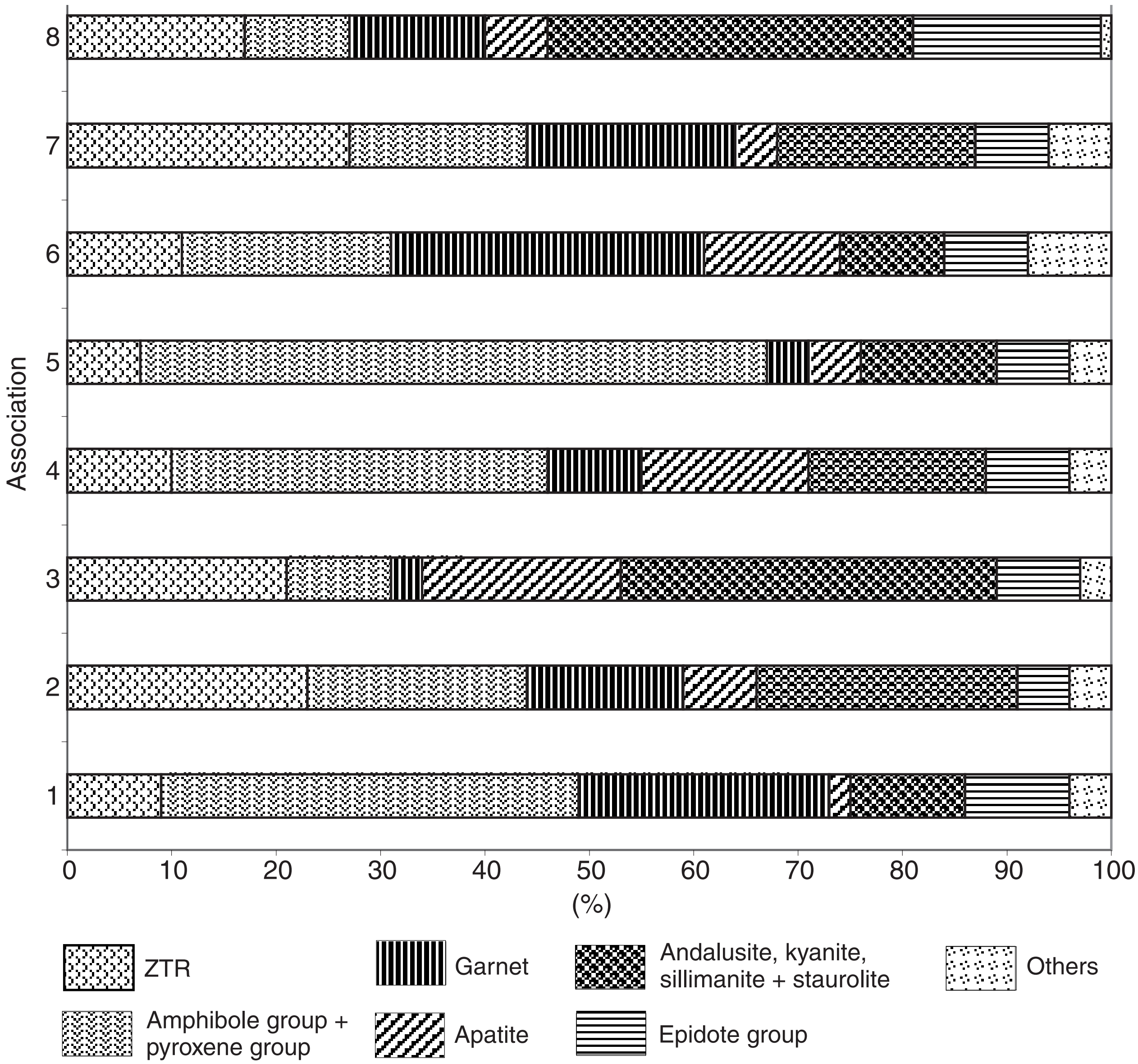

Figure F2. Distribution of heavy mineral associations, Holes 1071C and 1071F, 1072A, and 1073A.

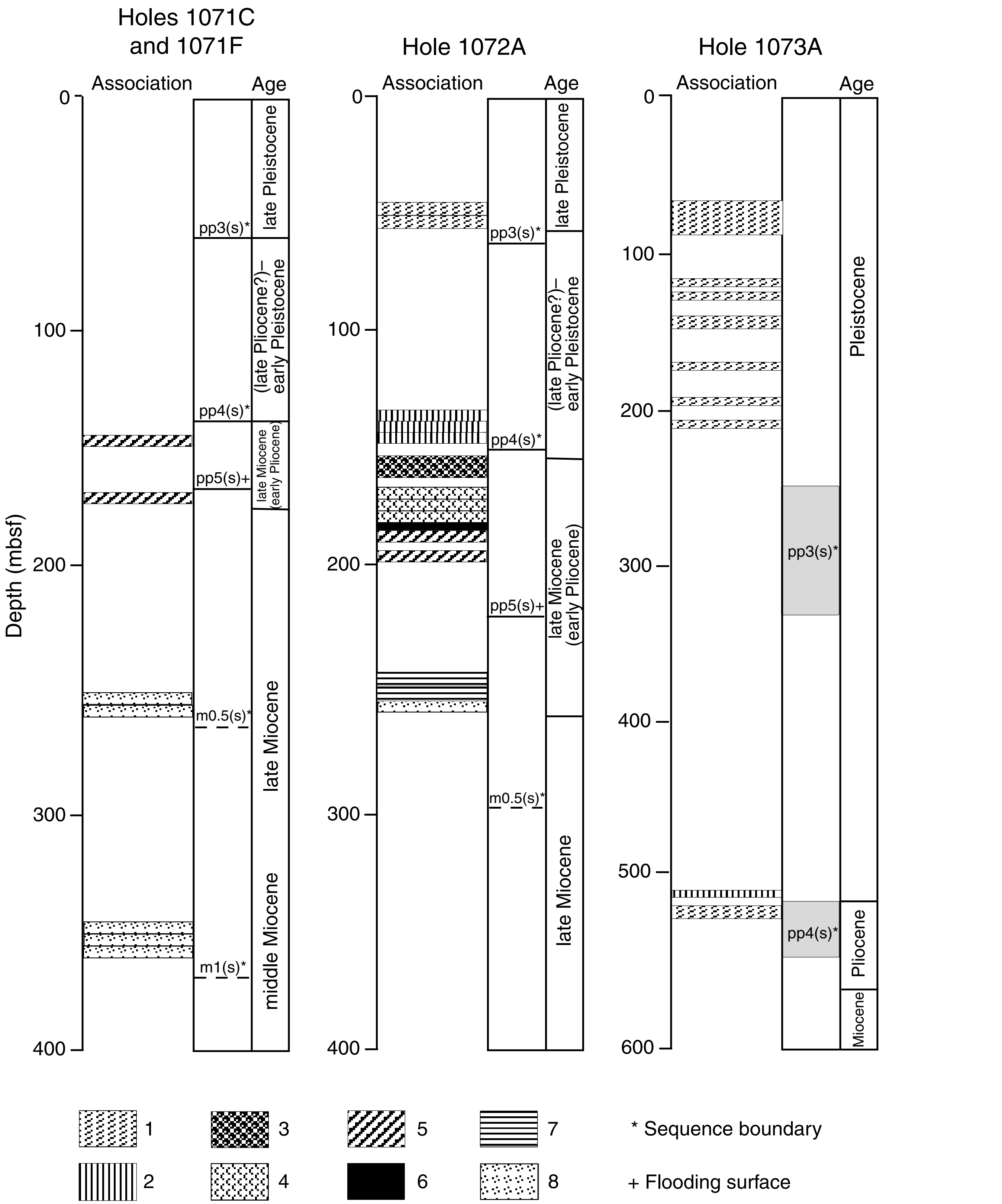

Table T1. Results of heavy mineral analyses, Holes 1071C and 1071F.

Sample	Zircon	Tourmaline	Rutile	Monazite	Staurolite	Garnet	Apatite	Sphene	Sillimanite	Kyanite	Epidote	Clinozoisite	Andalusite	Hypersthene	Enstatite	Diopside	Augite	Amphibole	Others	Total grain count
174A-1071F-																				
11R-1	3.0	10.0	3.5	0.0	7.5	6.0	4.0	1.5	19.0	2.50	18.0	7.5	0.0	0.5	1.5	2.0	0.0	10.0	4.0	149.0
10R-3	2.0	10.0	0.0	0.5	10.0	11.5	14.5	1.0	12.0	5.00	18.0	3.5	0.0	0.0	2.0	1.0	0.0	5.5	4.5	230.0
9R-3	0.5	10.5	1.5	0.0	6.5	11.5	4.5	1.5	26.0	5.50	19.0	4.5	0.0	1.0	0.0	0.0	0.0	4.0	3.5	213.0
174A-1071C-																				
25X-4	10.0	10.5	4.0	2.0	23.5	15.0	2.0	3.0	7.0	7.00	7.0	3.5	0.0	0.0	0.0	0.5	0.0	3.5	1.5	271.0
25X-1	2.0	12.0	2.5	0.0	6.5	11.5	5.0	1.0	21.5	3.50	15.0	6.5	0.0	2.5	0.5	1.0	1.0	8.0	1.0	254.0
16X-2	18.5	10.0	1.5	3.5	11.5	20.5	6.0	6.5	1.0	3.00	5.0	1.0	1.0	0.0	0.0	2.0	0.0	5.5	4.5	206.0
11X-3	0.5	7.5	0.0	0.0	2.5	4.0	5.0	0.0	10.0	0.53	6.5	1.0	0.0	2.0	0.0	1.5	1.0	56.0	1.5	197.0

Note: Except for total grain counts, all values are in percent.

Table T2. Results of heavy mineral analyses, Hole 1072A.

Sample	Zircon	Tourmaline	Rutile	Monazite	Staurolite	Garnet	Apatite	Sphene	Sillimanite	Kyanite	Epidote	Clinozoisite	Andalusite	Hypersthene	Enstatite	Diopside	Augite	Amphibole	Others	Total grain count
174A-1072A-																				
4R-3	2.0	5.5	0.0	1.5	5.5	27.0	2.0	0.0	6.50	0.0	7.0	2.0	0.0	2.5	0.0	3.5	2.5	27.5	4.5	223.0
5R-1	4.5	5.5	0.0	0.0	4.5	21.5	2.5	0.0	4.50	1.0	6.5	3.0	0.0	4.5	0.0	0.0	2.5	36.0	4.0	254.0
22R-3	5.5	13.0	3.5	1.0	10.0	13.0	10.0	0.0	7.50	0.0	2.0	2.0	0.0	0.0	0.0	2.0	3.5	22.0	4.5	108.0
24R-2	2.5	14.5	4.5	2.5	21.0	20.0	6.0	0.0	8.00	0.0	1.5	2.5	0.0	0.0	0.0	0.0	0.0	13.0	4.0	129.0
25R-1	3.5	21.0	1.5	0.0	15.5	10.5	4.5	0.0	12.50	1.0	6.0	1.5	0.0	0.0	0.0	3.0	0.5	14.5	4.5	179.0
26R-1	6.5	5.0	4.5	5.0	4.0	1.5	15.0	2.0	27.50	5.0	3.0	5.0	2.5	3.5	0.0	6.0	0.0	1.5	3.5	202.0
27R-1	15.0	4.5	5.5	2.0	0.0	4.5	20.5	0.0	28.50	3.5	2.0	4.5	0.0	0.0	0.0	3.5	0.0	5.5	1.0	92.0
29R-2	5.0	8.0	0.0	0.0	0.0	10.0	10.5	0.0	15.00	1.0	8.0	2.0	0.5	1.0	0.0	6.0	1.5	27.0	5.5	223.0
31R-3	5.5	2.0	0.0	0.0	0.0	5.5	16.0	0.0	21.50	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.0	0.0	56.0
34R-3	2.0	7.0	1.0	0.0	1.0	7.5	3.0	2.0	12.50	1.5	4.5	1.5	0.5	1.5	0.0	2.0	2.0	32.0	2.0	282.0
35R-3	2.0	5.5	1.0	0.5	3.5	4.5	7.0	0.0	8.50	0.1	3.5	3.0	0.0	0.0	0.0	2.5	5.0	56.0	1.5	175.0
36R-3	5.0	5.0	0.5	1.0	2.5	30.0	13.0	0.5	3.50	2.5	6.5	1.5	1.0	3.5	0.0	1.5	3.5	11.0	7.5	198.0
37R-2	2.0	2.5	0.0	0.5	1.5	4.0	3.0	0.0	11.00	1.0	5.0	1.5	0.5	1.0	3.0	1.5	6.0	1.5	1.5	239.0
46R-5	13.0	6.0	4.5	0.5	6.0	14.5	2.0	0.0	11.50	1.0	4.0	4.0	0.0	0.0	3.5	2.5	1.0	25.0	1.0	212.0
46R-6	16.0	7.5	1.5	0.5	11.5	19.5	5.0	2.0	7.51	1.5	4.5	1.0	0.0	0.5	1.5	0.5	1.5	18.0	2.0	218.0
47R-1	8.0	8.5	0.5	0.5	25.5	16.0	2.5	0.5	11.00	5.0	5.5	1.0	0.0	2.0	0.0	0.0	0.0	10.5	2.5	188.0

Note: Except for total grain counts, all values are in percent.

Table T3. Results of heavy mineral analyses, Hole 1073A.

Sample	Zircon	Tourmaline	Rutile	Monazite	Staurolite	Garnet	Apatite	Sphene	Sillimanite	Kyanite	Epidote	Clinozoisite	Andalusite	Hypersthene	Enstatite	Diopside	Augite	Amphibole	Others	Total grain count
174A-1073A-																				
9H-4	1.0	3.5	0.0	0.0	4.0	19. 5	4.0	0.0	5.0	2.0	8.0	4.0	0.0	6.0	0.5	6.5	5.5	19.5	11.0	254.0
9H-4	1.0	3.5	1.0	1.0	2.5	15.0	2.5	0.0	3.0	0.0	6.5	4.0	0.0	5.0	2.0	3.5	4.5	28.5	166.0	223.0
9H-5	3.0	4.0	1.0	0.5	4.0	14.0	4.5	0.0	4.0	1.5	5.0	3.0	0.0	4.5	0.5	6.5	3.0	35.5	5.0	211.0
9H-6	3.0	3.0	0.0	1.5	4.0	20.5	2.5	0.0	3.5	1.0	7.5	2.0	0.0	5.0	0.0	5.0	3.0	38.5	5.5	201.0
13H-4	2.0	5.5	0.0	0.5	3.5	21.0	5.5	0.0	3.5	0.5	6.5	2.0	0.0	4.0	0.0	2.5	3.0	30.5	9.5	233.0
13H-4	3.5	1.5	0.0	1.0	9.5	30.5	1.0	0.0	1.5	0.0	3.5	1.5	0.0	2.0	0.0	6.0	3.0	30.0	5.0	241.0
15H-2	7.5	2.5	1.0	0.0	1.5	12.5	12.5	0.0	14.0	2.0	2.5	1.0	0.0	1.0	0.0	2.0	1.0	36.0	1.5	185.0
15H-6	0.5	4.5	2.5	1.0	1.5	28.5	4.5	0.5	1.5	0.5	6.0	1.5	0.0	4.0	0.0	4.0	8.5	26.0	4.0	288.0
16H-3	2.0	2.5	1.5	0.0	2.0	23.0	2.0	0.0	1.5	0.0	8.5	1.5	0.0	5.5	0.0	3.5	4.5	37.0	4.0	237.0
16H-7	1.0	1.5	0.0	3.0	3.0	15.0	2.0	0.0	2.5	0.5	7.0	1.5	0.0	7.5	0.0	4.5	6.5	43.5	3.5	237.0
17H-3	1.0	4.5	1.0	0.5	3.0	19.0	6.5	0.0	1.5	1.5	4.5	1.0	1.0	3.5	0.0	3.5	5.0	37.0	6.0	256.0
21H-4	0.5	5.5	1.5	1.0	2.0	11.0	2.5	0.0	3.5	0.5	9.0	3.0	0.0	3.5	0.0	6.0	12.5	35.5	3.5	238.0
23H-5	1.5	3.5	0.0	3.0	5.5	23.5	1.5	0.0	5.5	0.5	6.5	1.5	0.0	0.5	0.0	5.0	2.0	31.5	5.0	251.0
57X-1	2.5	15.0	1.5	1.5	13.0	13.5	4.5	0.0	6.0	0.0	5.5	2.5	4.0	1.5	0.0	2.0	2.0	19.0	6.0	148.0
57X-2	3.0	19.5	0.0	1.5	5.5	22.5	1.5	0.0	14.0	1.5	0.0	0.0	4.0	0.0	0.0	0.0	1.5	22.5	3.0	71.0
57X-3	0.0	7.0	1.5	0.5	6.0	12.5	7.5	0.0	5.5	0.0	13.5	1.5	0.0	0.0	0.0	2.0	1.0	39.5	2.5	211.0
57X-4	2.0	2.0	1.0	1.0	11.5	16.0	2.5	1.0	4.5	0.0	14.0	2.0	1.0	1.0	2.0	1.0	2.0	33.5	3.5	113.0
57X-6	2.5	6.5	0.0	0.0	6.5	17.0	4.0	0.0	4.0	1.5	6.5	1.5	0.0	0.0	1.5	2.5	1.5	44.5	0.0	76.0

Note: Except for total grain counts, all values are in percent.

Table T4. Heavy minerals of Holes 1071A, 1071F, 1072A, and 1073A.

Amphiboles	Different hornblende varieties and Fe/Mg/Mn-amphiboles occur.
Hornblendes	Brown, green, and blue-green hornblende types can be distinguished on optical grounds. Grains are prismatic, but well-rounded grains also occur. Irregular and jagged edges are common. Etching and grain skeletons are rare.
Fe/Mg/Mn-amphiboles	Antophyllite and gedrite occur only in a few samples.
Andalusite	Only colorless varieties with a marked pleochroism occur. Grains are irregularly splintery to subrounded. Corrosion features are rare.
Apatite	Colorless and brownish yellowish (collophane) varieties occur. The shape of the grains ranges from prismatic with subrounded edges to very well rounded and nearly circular. Irregular grain fragments may also occur. Corrosion features are frequent and intensive.
Epidote group	Optical identification of zoisite, clinozoisite, and epidote is occasionally ambiguous. Epidote (greenish yellow, pleochroitic minerals) and zoisite/clinozoisite (colorless grains) were distinguished due to color.
Epidote	Angular, isometric grains are common. Well-rounded grains are rare. Corrosion features and pale colors indicate incipient decomposition.
Clinozoisite	Short, prismatic, partly subrounded grains occur. Etching features along the edges are frequent.
Garnet	Three varieties occur: colorless, pale pink, and salmon pink garnets, which all belong to the pyralspite group. Grains are spherical to sharp-cornered irregular and well rounded to angular. Garnets reveal a high variety of corrosion features as described by Grimm (1973).
Kyanite	Colorless to light blue varieties occur. Mainly prismatic, subrounded grains; inclusions are common. Fibrous etching features may occur along edges.
Monazit	Grains exhibit a light yellow color and are rounded to well rounded. Grain surfaces are rough and reveal small brownish to black spots.
Pyroxenes	Orthopyroxenes as well as clinopyroxenes occur. Enstatite (colorless, optically positive, clear pleochroism), hypersthene (pale pink, optically negative, clear pleochroism), diopside (colorless), and augite (green) can be distinguished on optical grounds.
Augite	Mainly greenish, with short prisms and fragments. Partly rounded, but most of the grains exhibit etching features (hacksaw features along edges and even skeletal grains).
Diopside	Mostly prismatic, colorless grains. Moderately rounded grains as well as grains exhibiting etching features occur.
Enstatite	Colorless, prismatic grains.
Hypersthene	Pale pink, angular to subangular, prismatic grains with a marked pleochroism. Brownish exsolution lamellae are common.
Rutile	Brownish black and red to reddish black varieties occur. Grains are subrounded to well rounded.
Sillimanite	Mainly subrounded, prismatic grains and fragments. Rare specimens of fibrolite occur. Etching features are rare.
Sphene	Colorless, subangular to subrounded grains.
Staurolite	Grains exhibit variable yellow colors. Most grains are irregular and angular. Some grains are well rounded. Corrosion features are frequent and exhibit warts, frayed edges, and perforated grain skeletons.
Tourmaline	Brown, colorless; blue and red (with decreasing frequency) varieties occur. Grains are mainly short-prismatic and well rounded. Inclusions are common.
Zircon	Colorless minerals prevail. Yellowish and pale pink varieties are rare. Mostly well-rounded and spheroidal grains. Some grains exhibit rough and pitted surfaces. Fragments of euhedral forms (some with well-developed zoning) occur.