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HEAVY MINERALS IN STREAM SANDS OF THE SOUTHERN HAZARA DISTRICT, PAKISTAN

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HEAVY MINERALS IN STREAM SANDS OF THE SOUTHERN HAZARA DISTRICT, PAKISTAN

by

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ABSTRACT

The areal distribution of heavy minerals in 99 samples from stream sands in the southern Hazara District, West Pakistan, indicates that the metamorphic grade of the rocks in the area increases toward the northwest. Minerals of potential enonomic value in the heavy-mineral samples include scheelite from the Oghi-Batgram-Battal area and hematite from the Galdanian area. The total weight of magnetite sand grains transported down the Indus River past Darband is calculated to be about 200,000 tons per year, a quantity which may be of economic value. Radioactive minerals are not present in any of the samples in sufficient quantity to be of economic importance.

INTRODUCTION

For many years the Hazara District had the reputation of being one of the most highly mineralized areas of West Pakistan. This reputation was based on a few geological reports, some mining activity, and scattered occurrences of potential ore minerals. As a preliminary to later detailed work, a rapid general survey of the mineral potential of the southern Hazara District (figs. 1, 2) was made in 1961 and 1962 by geologists of the U. S. Geological Survey and the Geological Survey of Pakistan. The first part of this survey consisted of the examination

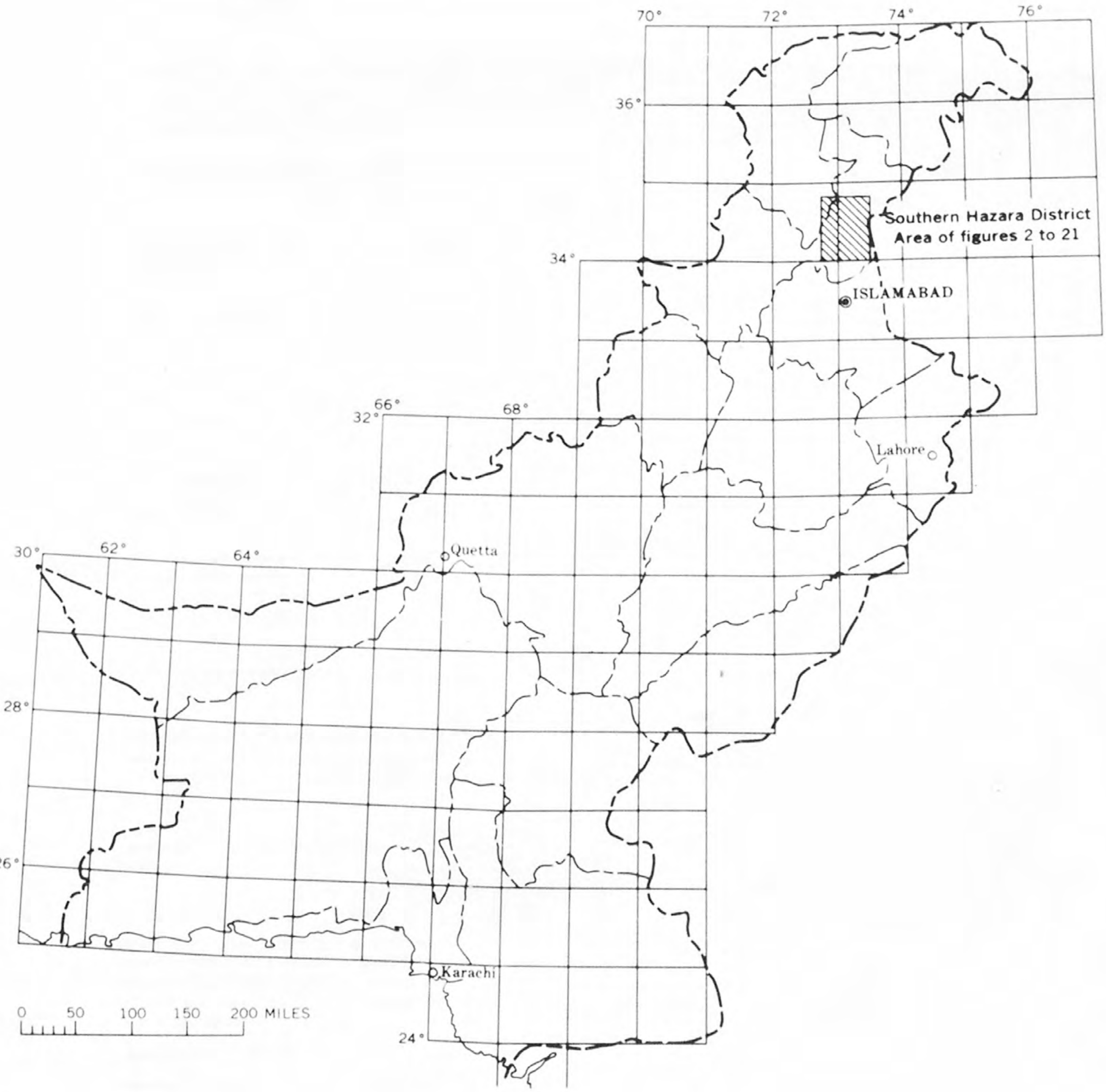

Figure 1.—Index map showing location of the southern Hazara District, Pakistan.

and evaluation of the known mineral showings of the area, the results of which are reported by Ali, Calkins, and Offield (1964).

The second part of this initial survey, carried out concurrently, was a heavy-mineral stream-sand sampling program. The author accompanied by M. S. Zafar of the Geological Survey of Pakistan spent about 6 weeks collecting stream-sand samples throughout the southern Hazara District. Most of the samples were collected near the roads which traverse the area (fig. 3), but samples from the Indus River and its tributaries in the northwestern part of the area were collected on a 10-day walking trip.

Acknowledgements

The author extends his thanks to the Assistant Commissioner at Oghi, the Chief Secretary of Swat State, and S. T. Ali of the Geological Survey of Pakistan for the numerous arrangements they made that facilitated fieldwork, and to the local inhabitants, especially in the tribal areas, for their hospitality, help, and interest.

J. J. Matzko, U. S. Geological Survey, and his assistants aided in the routine sample preparation and also in the microscopic identification of the rarer minerals. S. M. Haque of the Geological Survey of Pakistan helped with the quantitative calculations of the heavy minerals. Survey of Pakistan topographic sheets at a scale of 1 inch equals 1 mile were used as base maps.

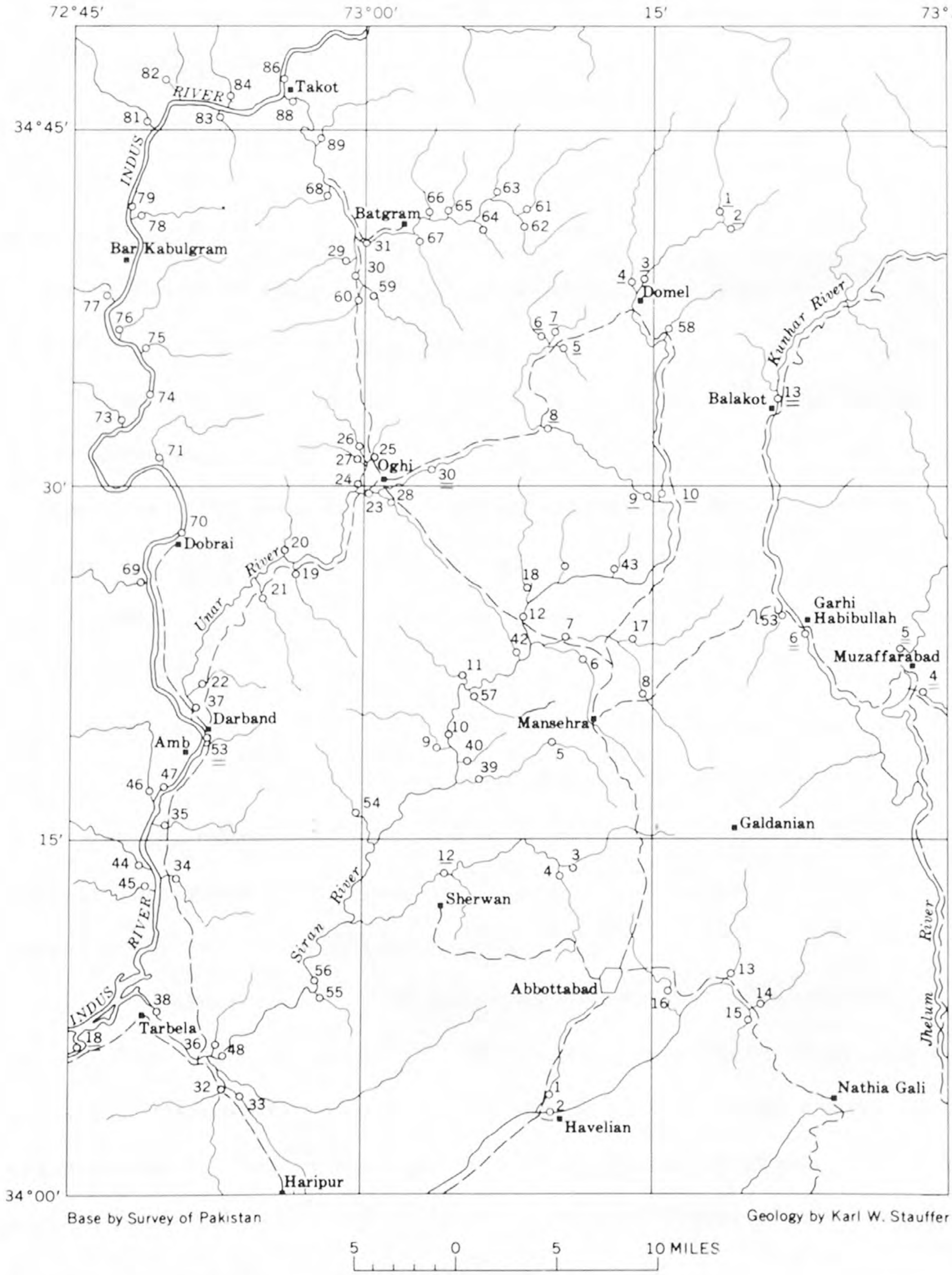

Figure 3.—Map showing heavy-mineral stream-sand samples collected in the southern Hazara District. TO samples of Table 1 underlined once. W samples underlined twice.

PURPOSE AND SCOPE OF STUDY

The field study was carried out because of the necessity for quickly determining some aspects of the gross regional mineral potential in the Hazara District. This report serves the purpose of describing how regional minerals exploration can be carried out utilizing relatively simple methods and a minimum of equipment; it recommends warranted further exploration.

The examination of the heavy minerals in stream sands is perhaps the quickest way to obtain an impression of the mineral potential of a large area. The sand in a streambed is derived from the entire drainage area of that particular stream. Mineralogical analysis of such a sand is in effect a very rapid general survey of the minerals present in the drainage area of the stream.

Most minerals of commercial value are heavy; that is, they have a specific gravity appreciably greater than quartz and feldspar. It is, therefore, necessary to examine only the heavier fraction of the minerals in a stream sand to obtain a general impression of the mineral potential of the drainage area.

In the Hazara District, 99 sand samples were collected within an area of about 1,500 square miles. The streams from which these samples were taken drain most of the southern Hazara District; the median drainage area covered by one sample is about 10 square miles. The heavy minerals of these samples probably represent most of the minerals of potential economic value in this area.

In addition to indicating the minerals of potential economic value a heavy-mineral suite indicates the general rock types present. From the heavy minerals alone one may readily distinguish different types of igneous and metamorphic terranes. The metamorphic grade may be quickly determined from such key minerals as chlorite, kyanite, and sillimanite. Some minerals such as scheelite and monazite, which are difficult to recognize in outcrop, are readily identified in a heavy-mineral study.

The limitations of a heavy-mineral sampling program should always be kept in mind. A mineral deposit must be exposed and subject to erosion to contribute to the stream sands; a deposit that is largely covered will contribute little or no detritus to the stream sands and may be missed. Furthermore, many of the most valuable ore minerals, especially the metal sulfides, decay rapidly in an oxidizing environment; such minerals are generally not found in heavy-mineral concentrates of stream sands. Valuable heavy minerals from an ore deposit may also be so diluted by minerals from the surrounding country rock that they constitute a mere trace of the detrital heavy minerals and thus appear quantitatively insignificant.

FIELD SAMPLING PROCEDURE

Before beginning the fieldwork, suitable stream-sand sampling locations were selected and plotted on a map of the southern Hazara District. All major streams were sampled at regular intervals along their courses, and their tributaries were sampled near the confluence with the major streams.

The initial sample consisted of three gold pans filled with sand chosen from a suitable locality in the streambed. The sand was panned down by the standard gold-panning methods to a semiconcentrate having a volume about one twentieth of the raw sample. This semiconcentrate was not further treated in the field.

ANALYTICAL PROCEDURE

In the laboratory the samples were further concentrated by panning; they were weighed and the magnetite was removed with a hand magnet. The rest of the sample was then placed in a separatory funnel filled with bromoform to remove the remaining light minerals. The concentrated heavy minerals were tested for scheelite with ultraviolet light and for radioactivity with a laboratory scaler.

To obtain a representative sample of the heavy minerals for microscopic study, the sample was split by coning and quartering to a suitably small portion, which was mounted in oil. The relative proportions of the heavy detrital minerals were determined by systematically counting a minimum of 250 grains with the help of a mechanical stage. This number has been shown to be statistically valid for the methods used in this study (Stauffer, unpub. data).

For the identification of the minerals under the microscope, all optical properties such as color, pleochroism, form, optical orientation, refractive index, birefringence, and interference figure were used. Reference works consulted included Krumbein and Pettijohn (1938), Larsen and Berman (1934), Milner (1940), Overstreet (1962), Rogers and Kerr (1942), Short (1948), and Winchell (1951 a,b).

The percentages of the minerals were then calculated. The magnetite percentage was calculated on the basis of weight, the percentages of all other minerals as grain percent. The presence of scheelite was expressed both as grain percent and as grains per gram of heavy minerals as determined under an ultraviolet light. The mineral content of the samples was recorded on table 1, and the distribution of individual heavy minerals was plotted and contoured on maps of the southern Hazara District (figs. 4 through 21). Sample 60-W-53, a gold-washer's concentrate of Indus River sand was not included in making these contour maps because it represents an extreme concentration of the heavy minerals and is not comparable with the other samples.

GEOLOGICAL INFORMATION

In addition to tracing potential ore minerals, the Hazara heavy-mineral study has provided information of general geologic interest.

Metamorphic grades

The grade of metamorphism of a rock is related to the physical and chemical conditions existing during metamorphism. Where metamorphic rocks are exposed over extensive areas, zones corresponding to different physical and chemical conditions of metamorphism may be present. Each zone in an area of progressive metamorphism is defined by an index mineral, whose first appearance, going from lower to higher grades, marks the outer limit of the zone.

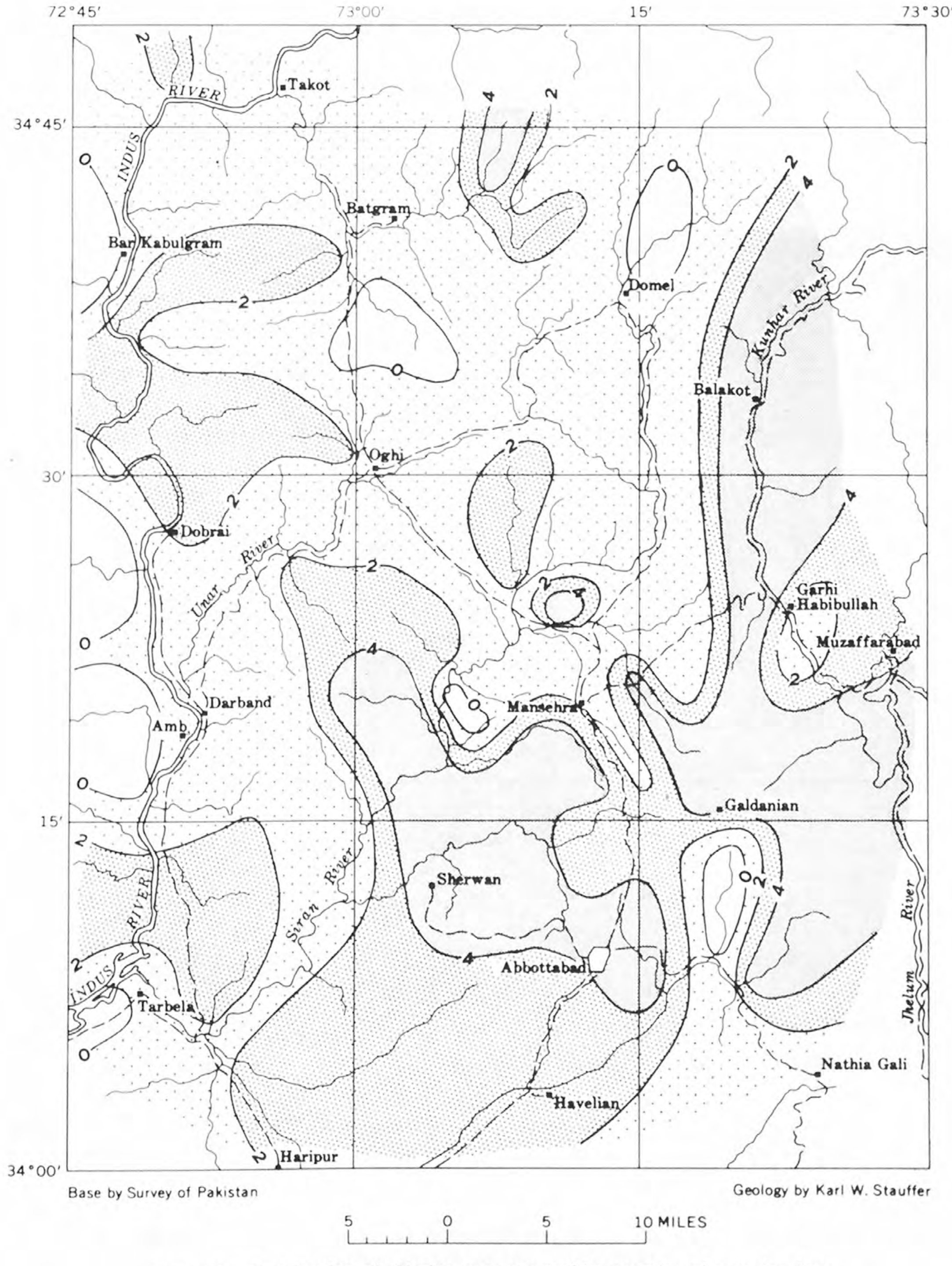

Figure 4.—Distribution of chlorite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

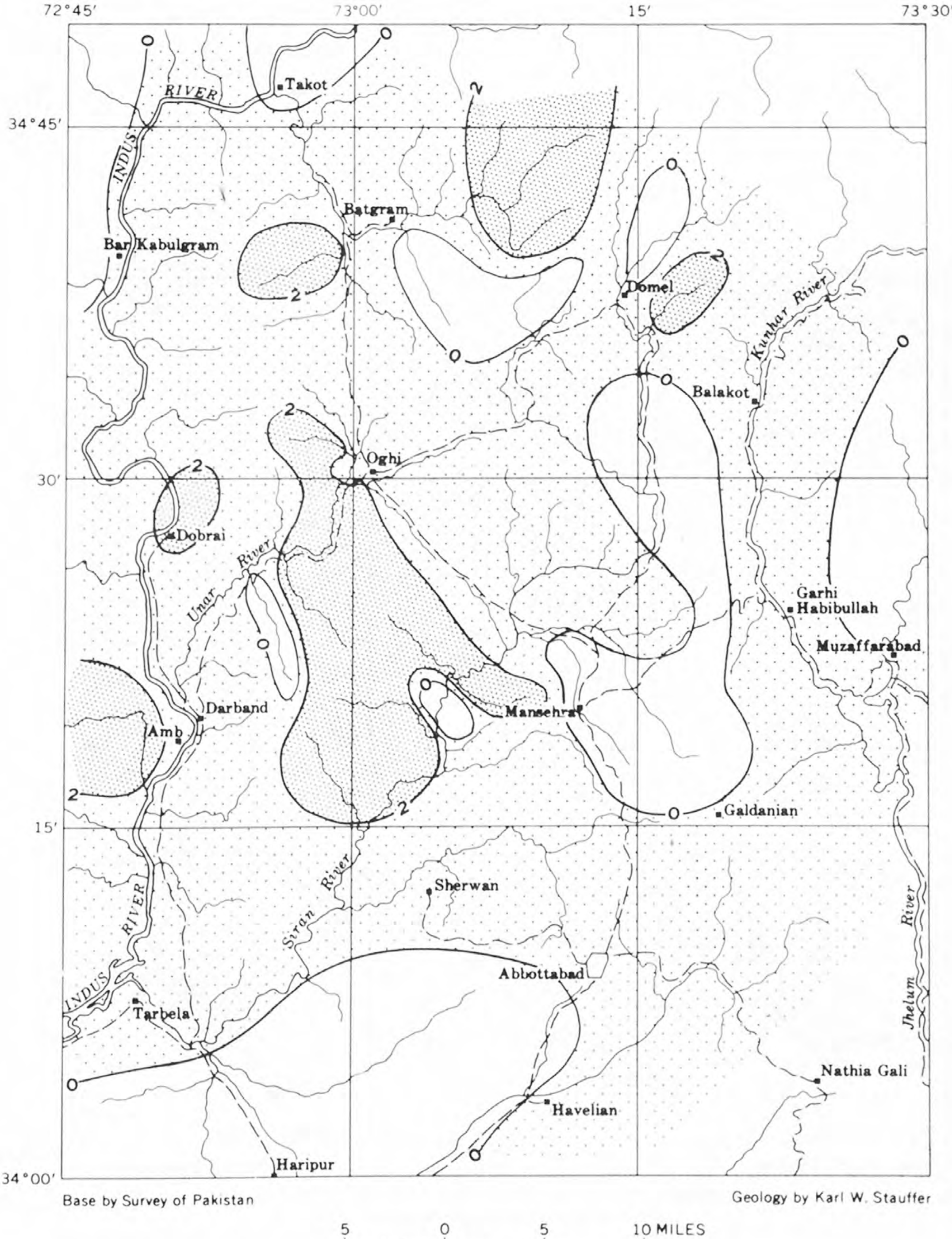

Figure 5.—Distribution of brown biotite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

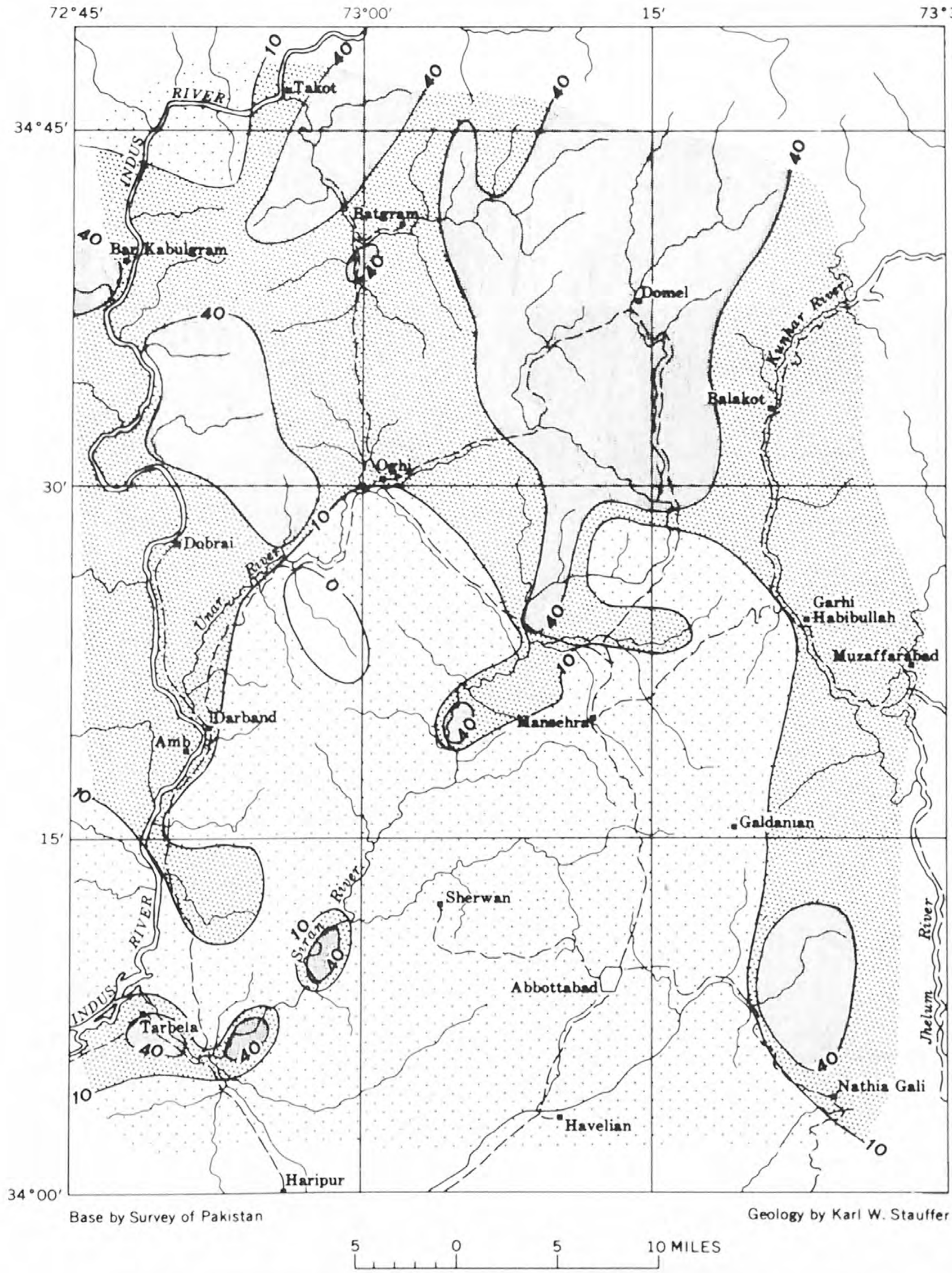

Figure 6.—Distribution of garnet as percent of heavy-mineral samples from southern Hazara District, Pakistan.

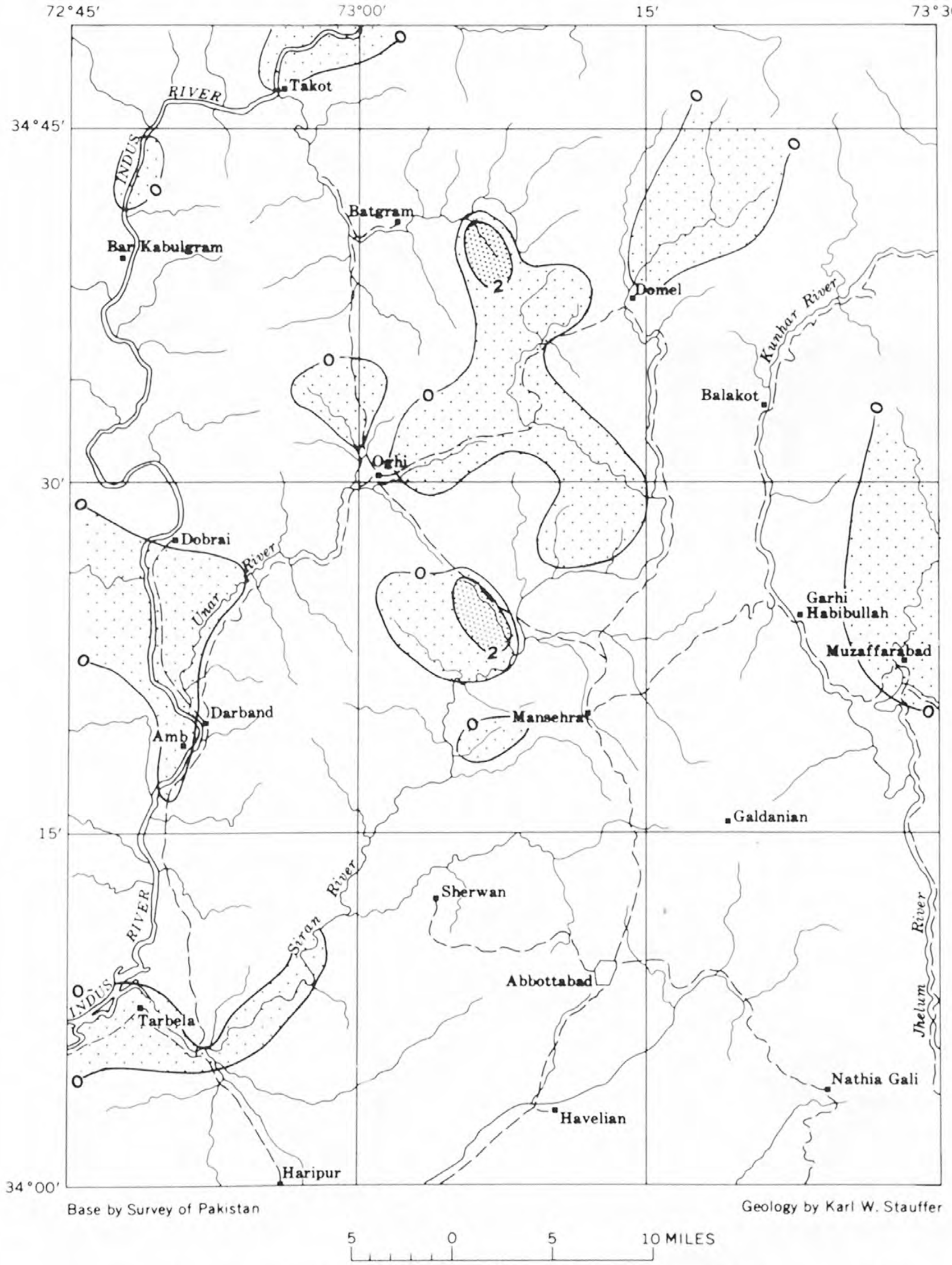

Figure 7.—Distribution of staurolite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

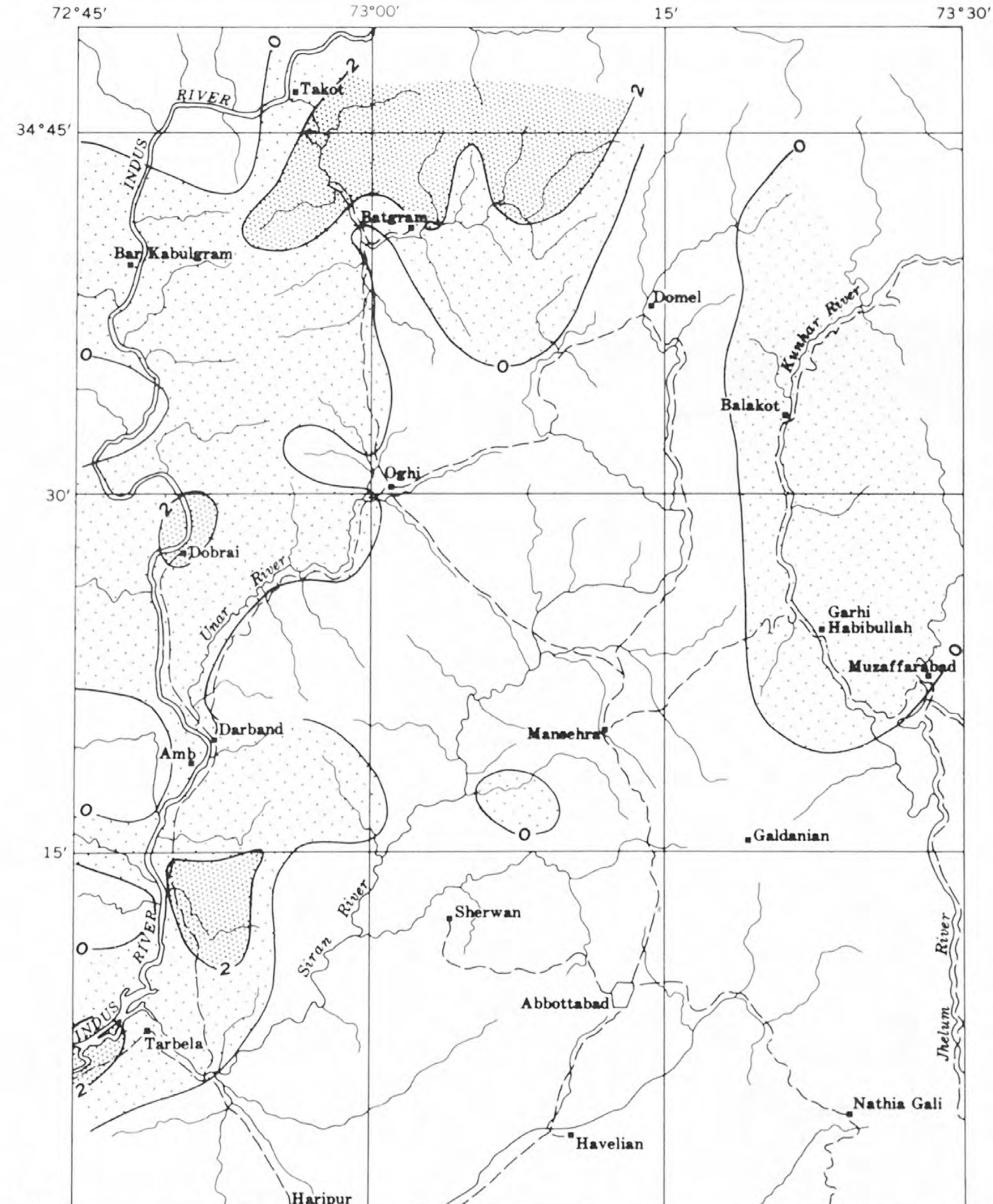

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Figure 8.—Distribution of kyanite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

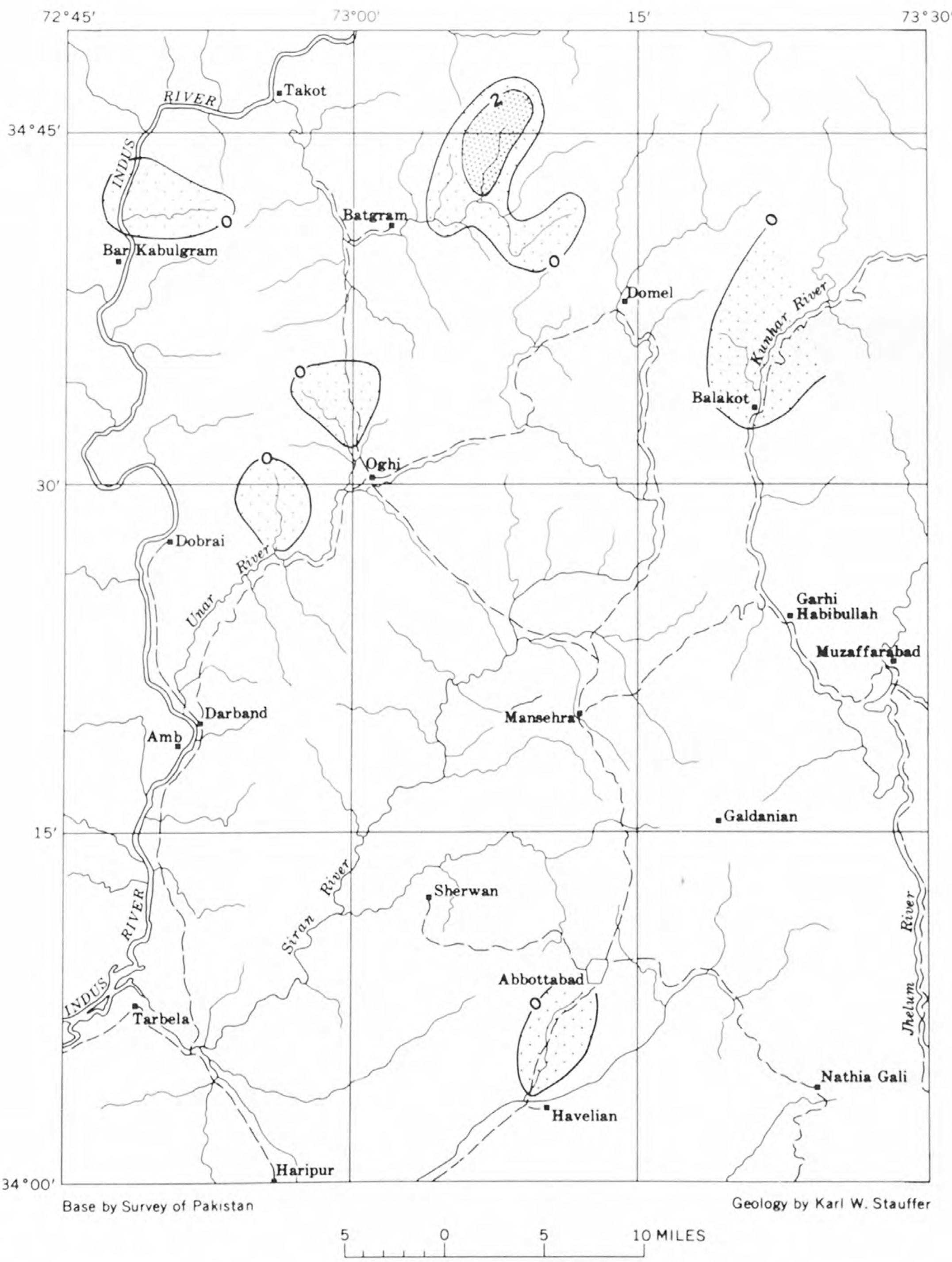

Figure 9.—Distribution of sillimanite as percent of heavy-mineral samples from southern Hazara District, Pakistan

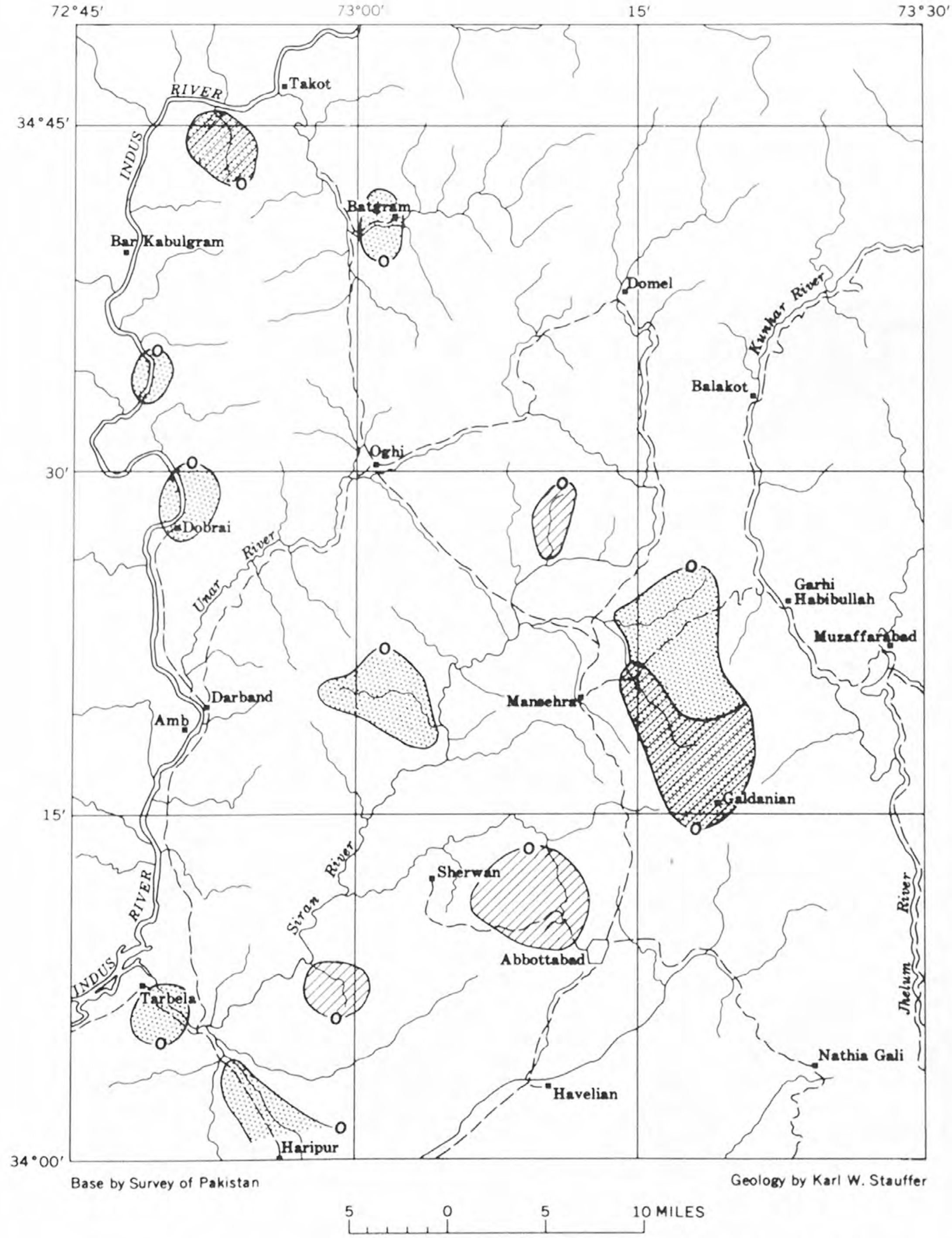

Figure 10.—Distribution of the volcanic materials oxyhornblende (oblique lines) and glass (stippled pattern) as percent of heavy-mineral samples from southern Hazara District, Pakistan.

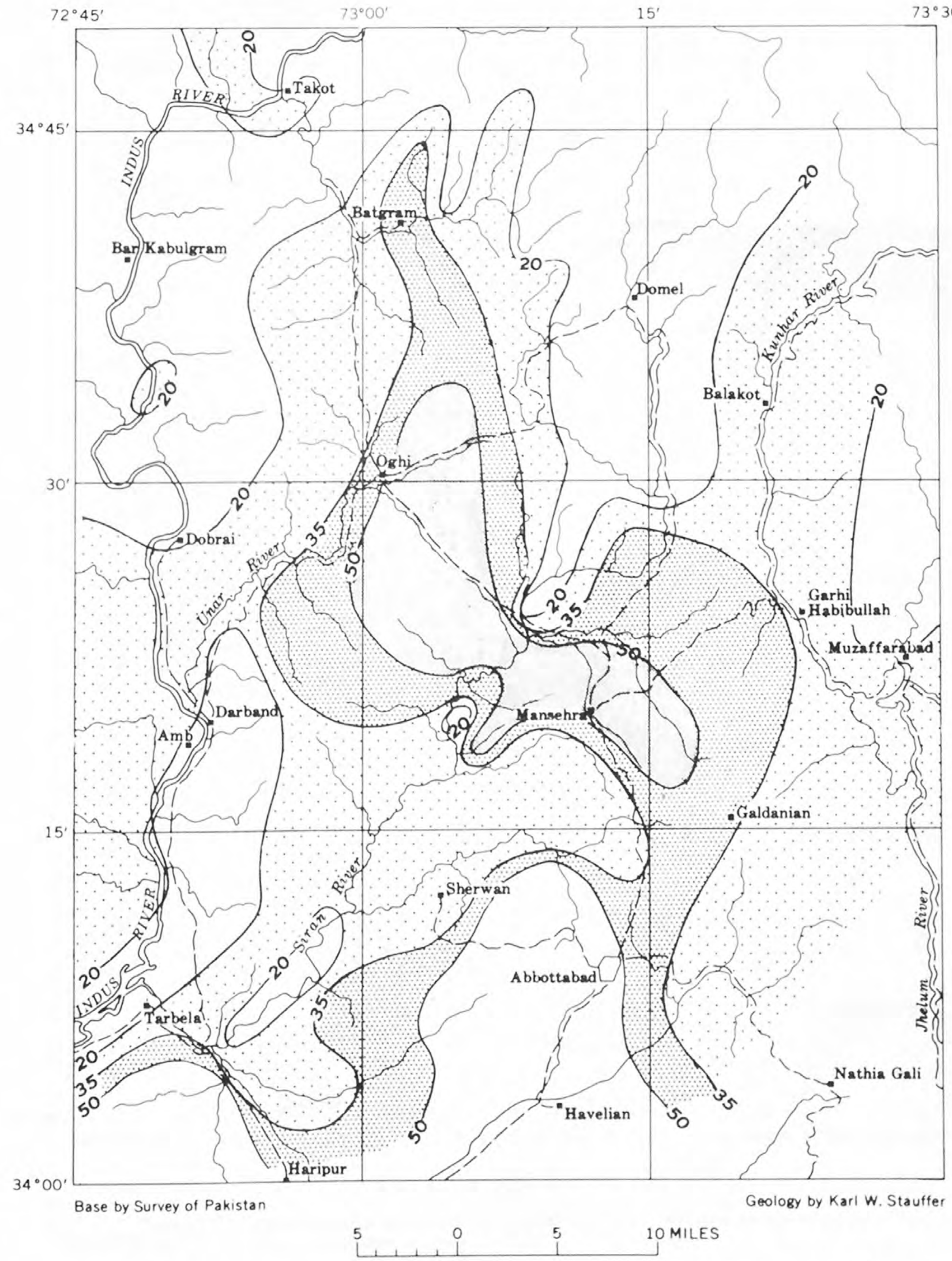

Figure 11.—Distribution of ilmenite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

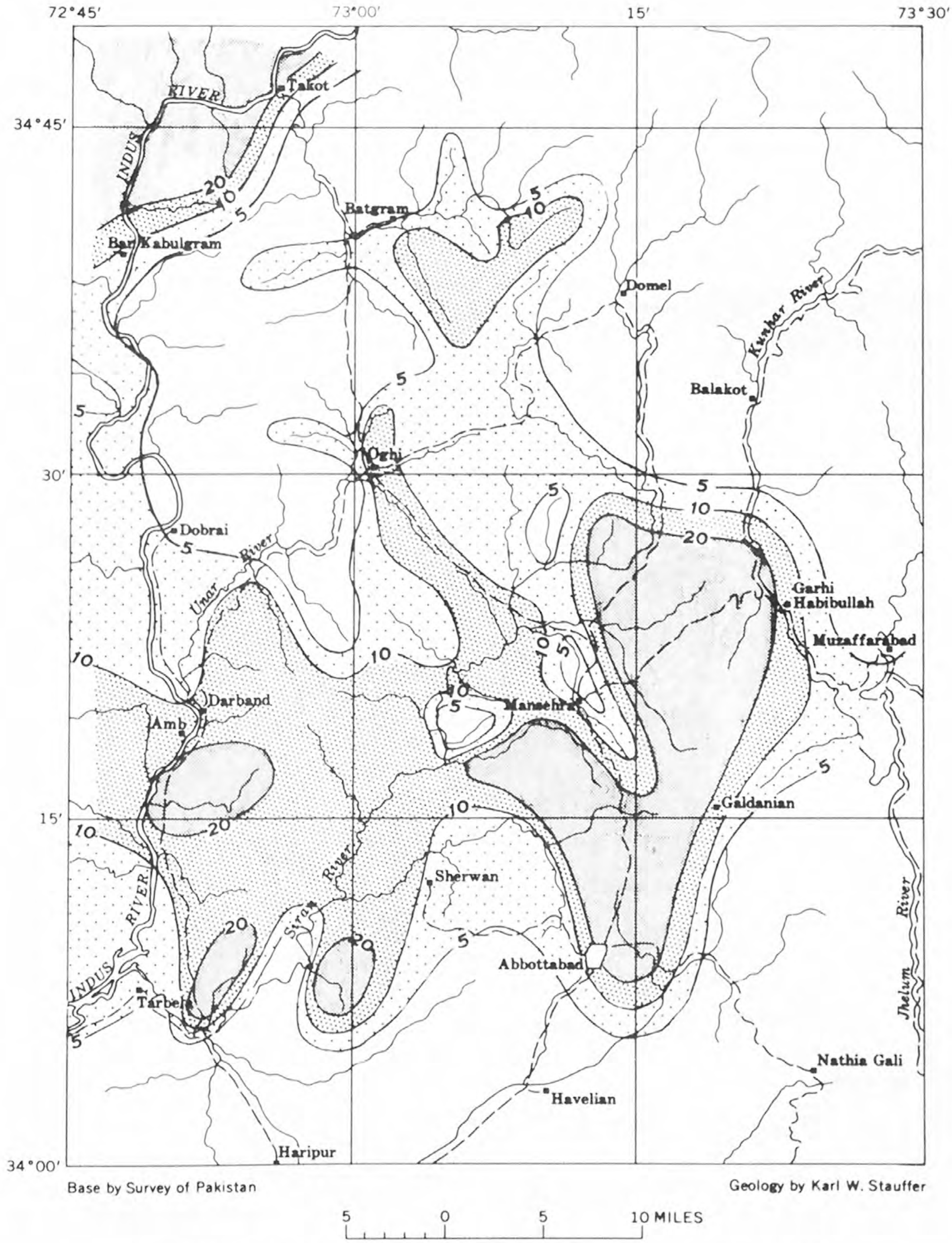

Figure 12.—Distribution of magnetite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

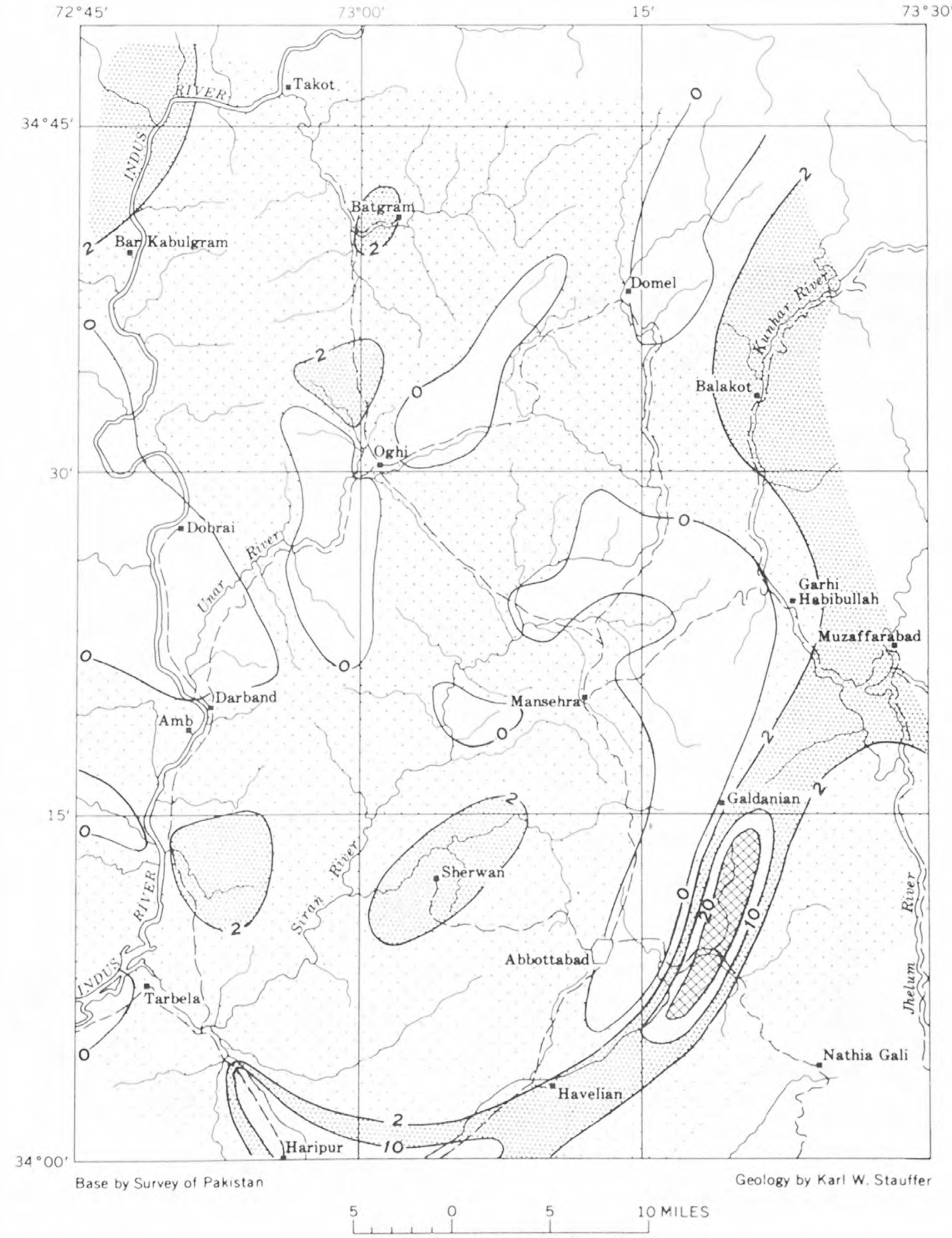

Figure 13.—Distribution of hematite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

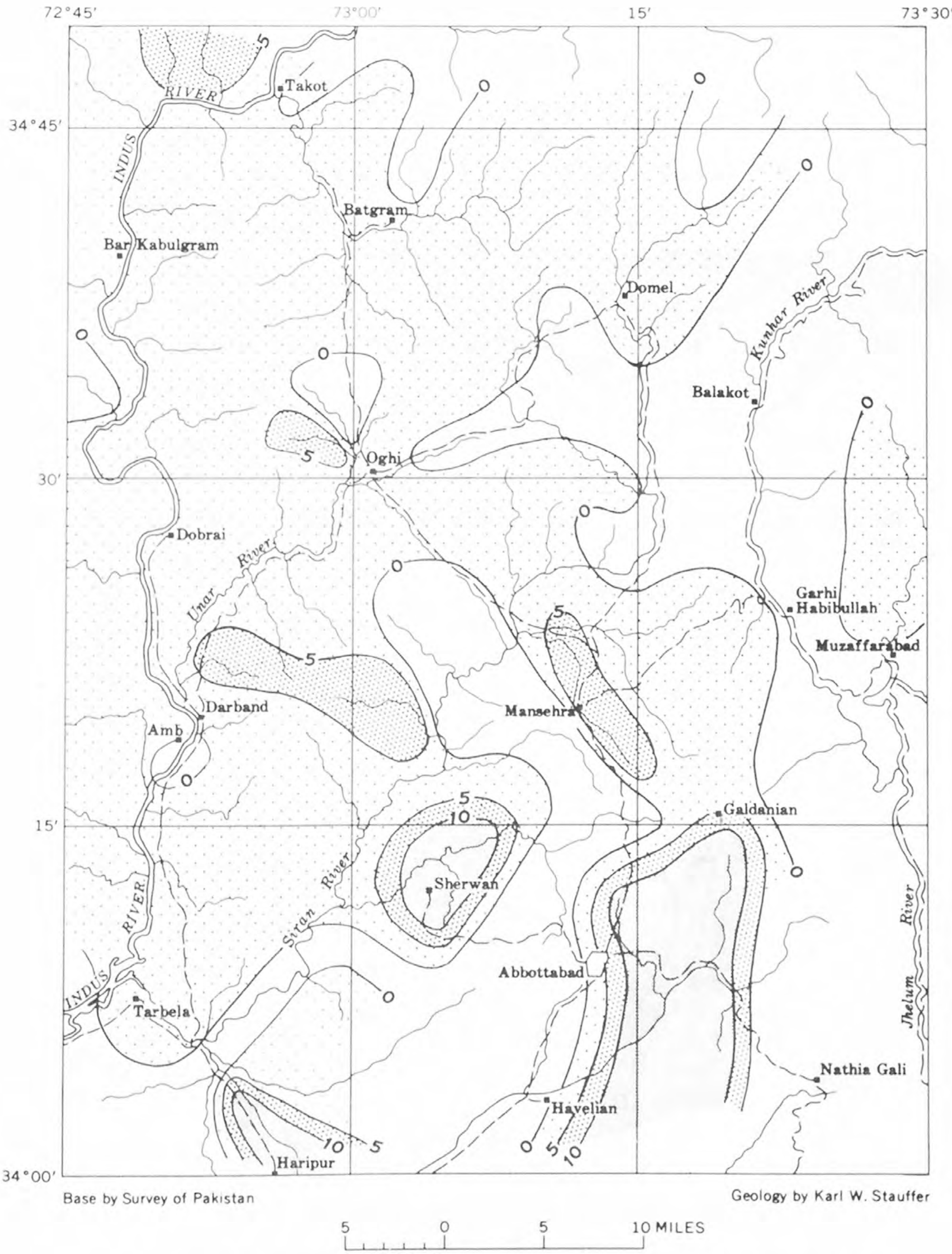

Figure 14.—Distribution of hydrous iron oxides as percent of heavy-mineral samples from southern Hazara District, Pakistan.

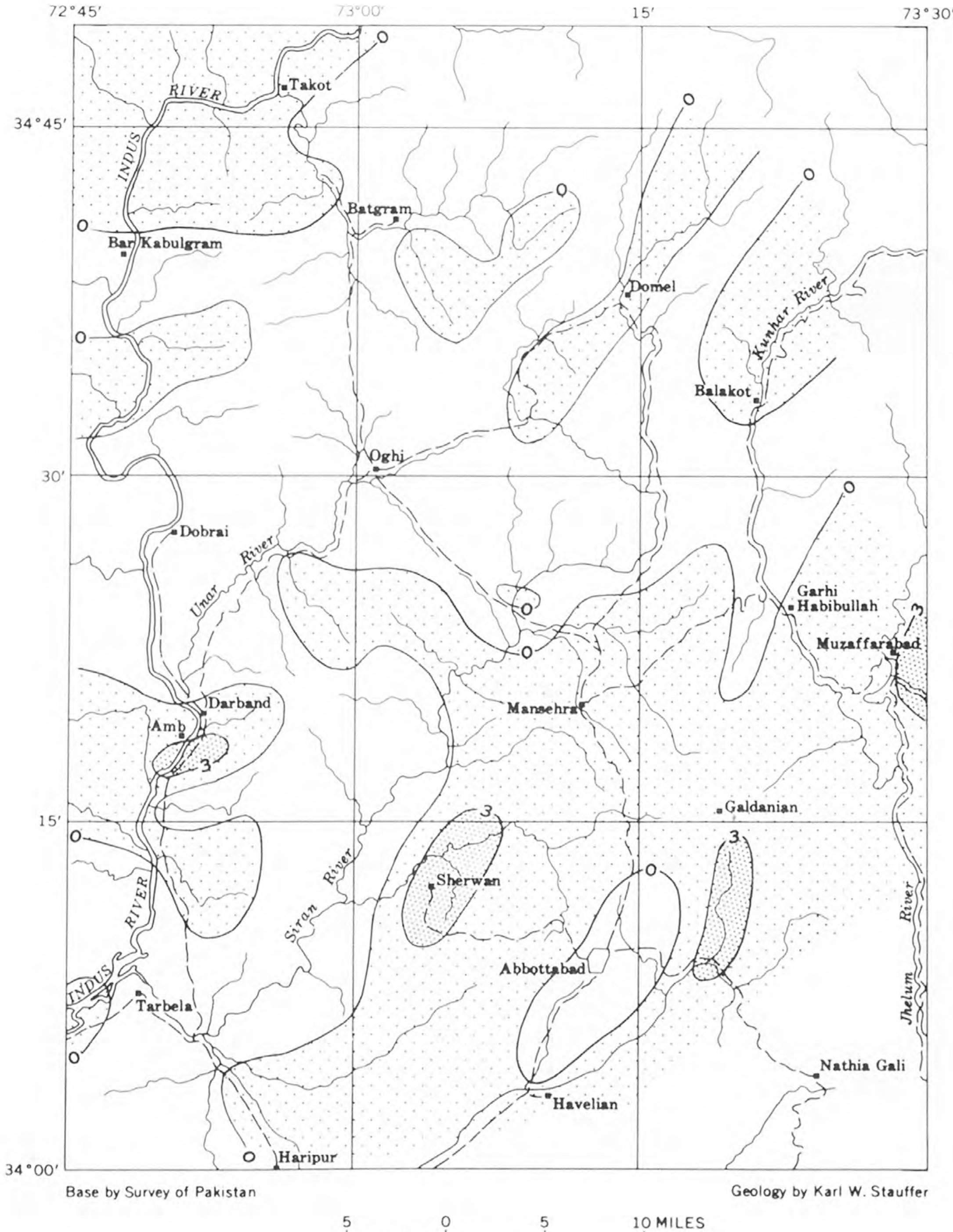

Figure 15.—Distribution of pyrite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

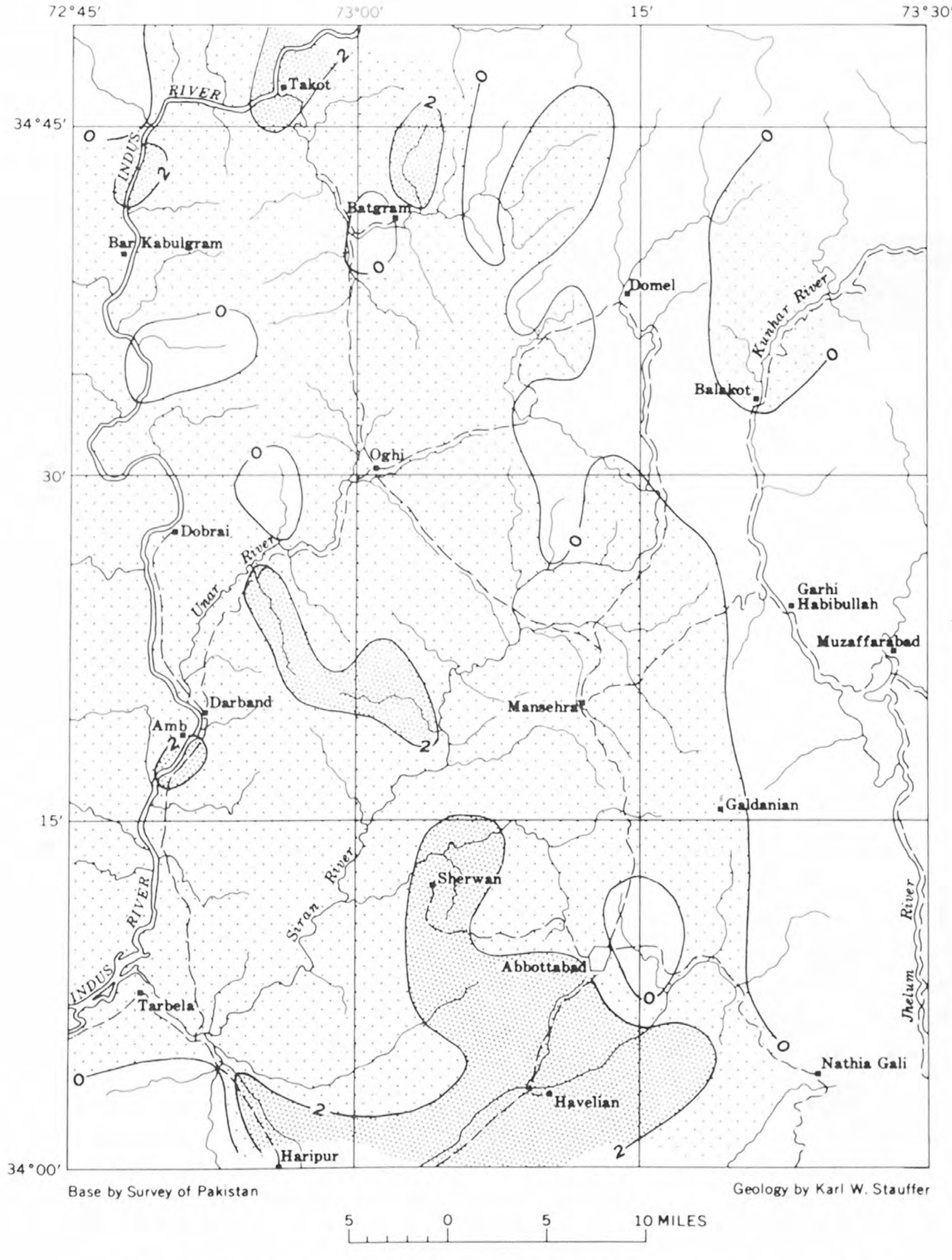

Figure 16.—Distribution of normal zircon as percent of heavy-mineral samples from southern Hazara District, Pakistan.

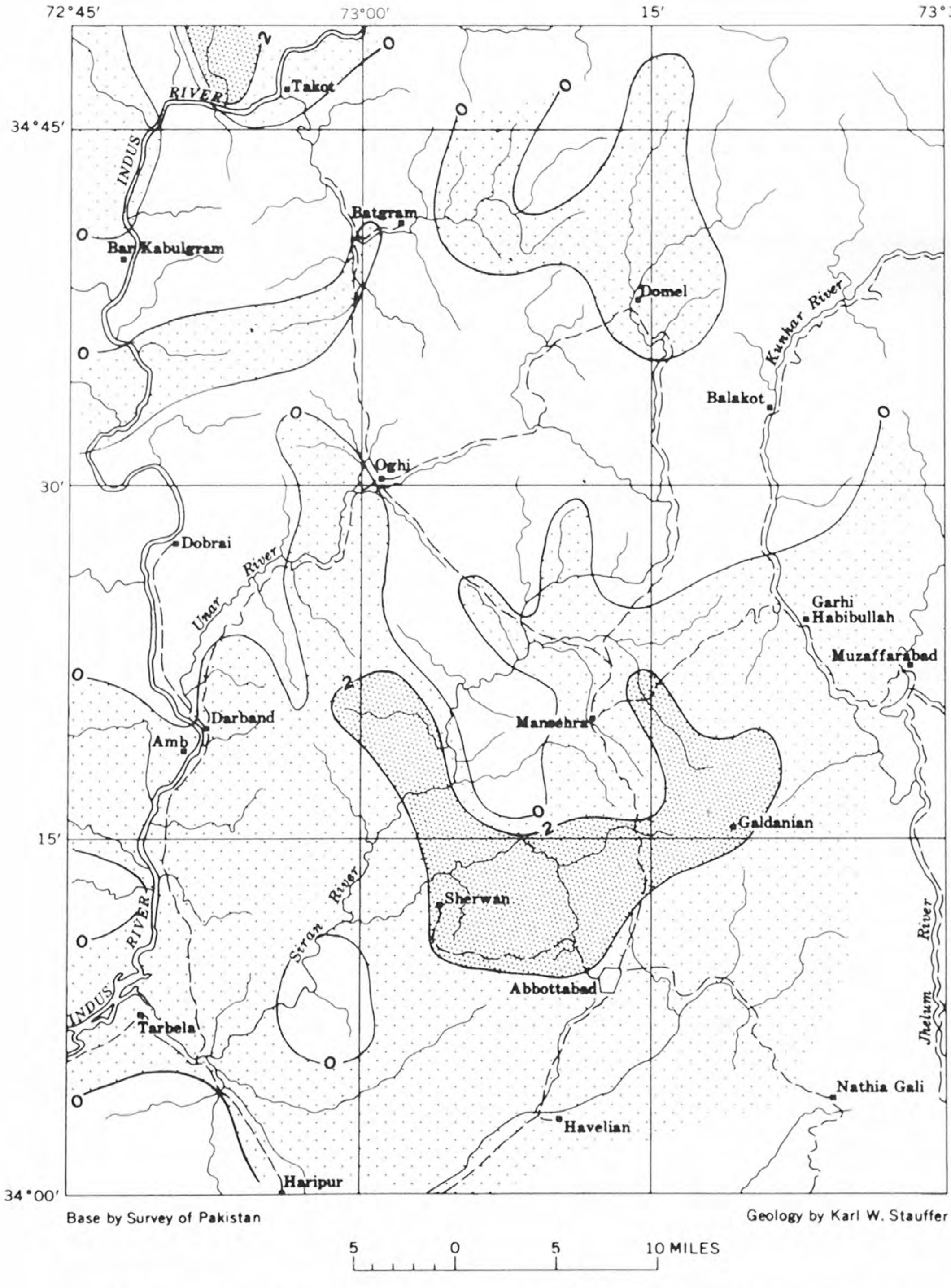

Figure 17.—Distribution of metamict zircon as percent of heavy-mineral samples from southern Hazara District, Pakistan.

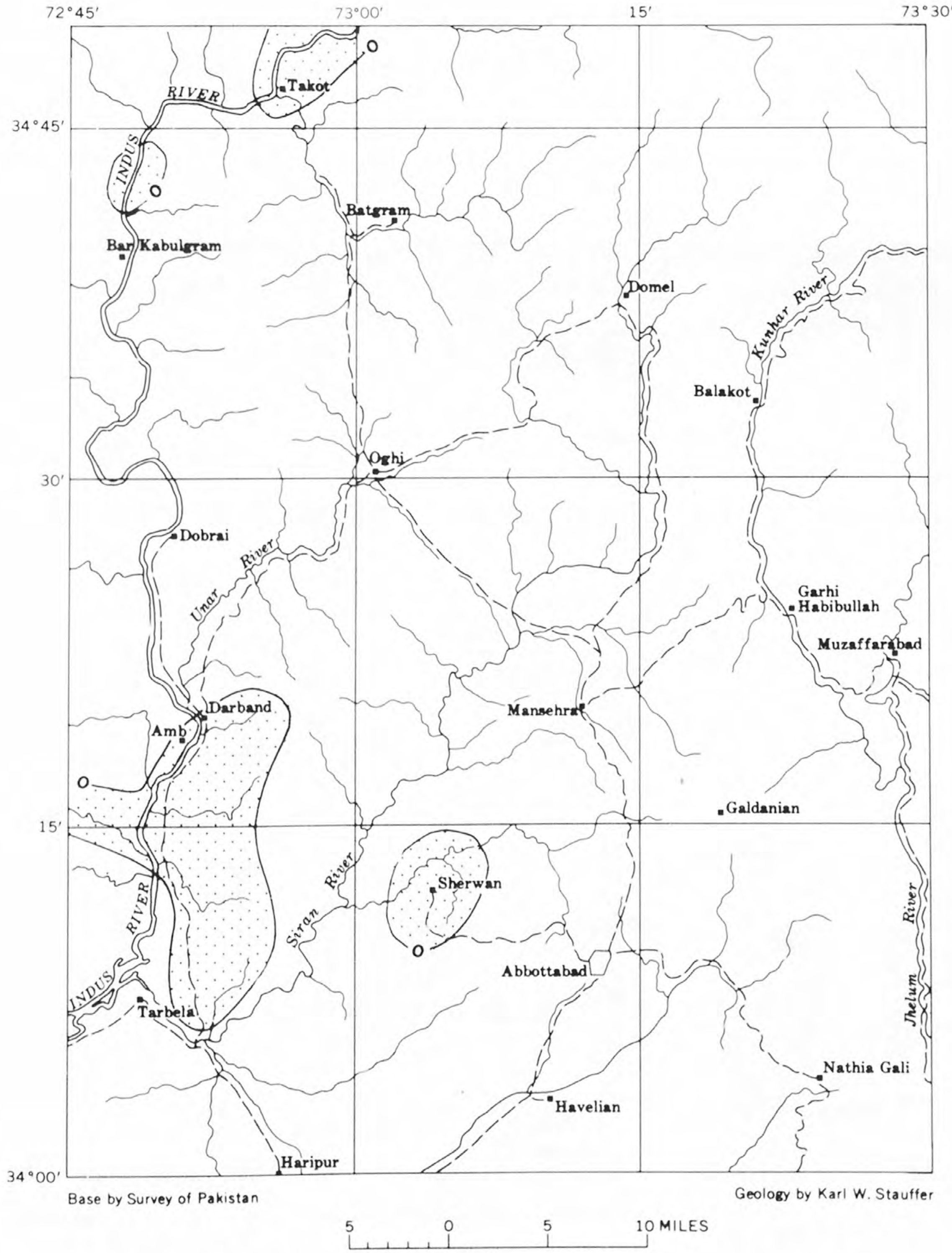

Figure 18.—Distribution of hyacinth zircon as percent of heavy-mineral samples from southern Hazara District, Pakistan.

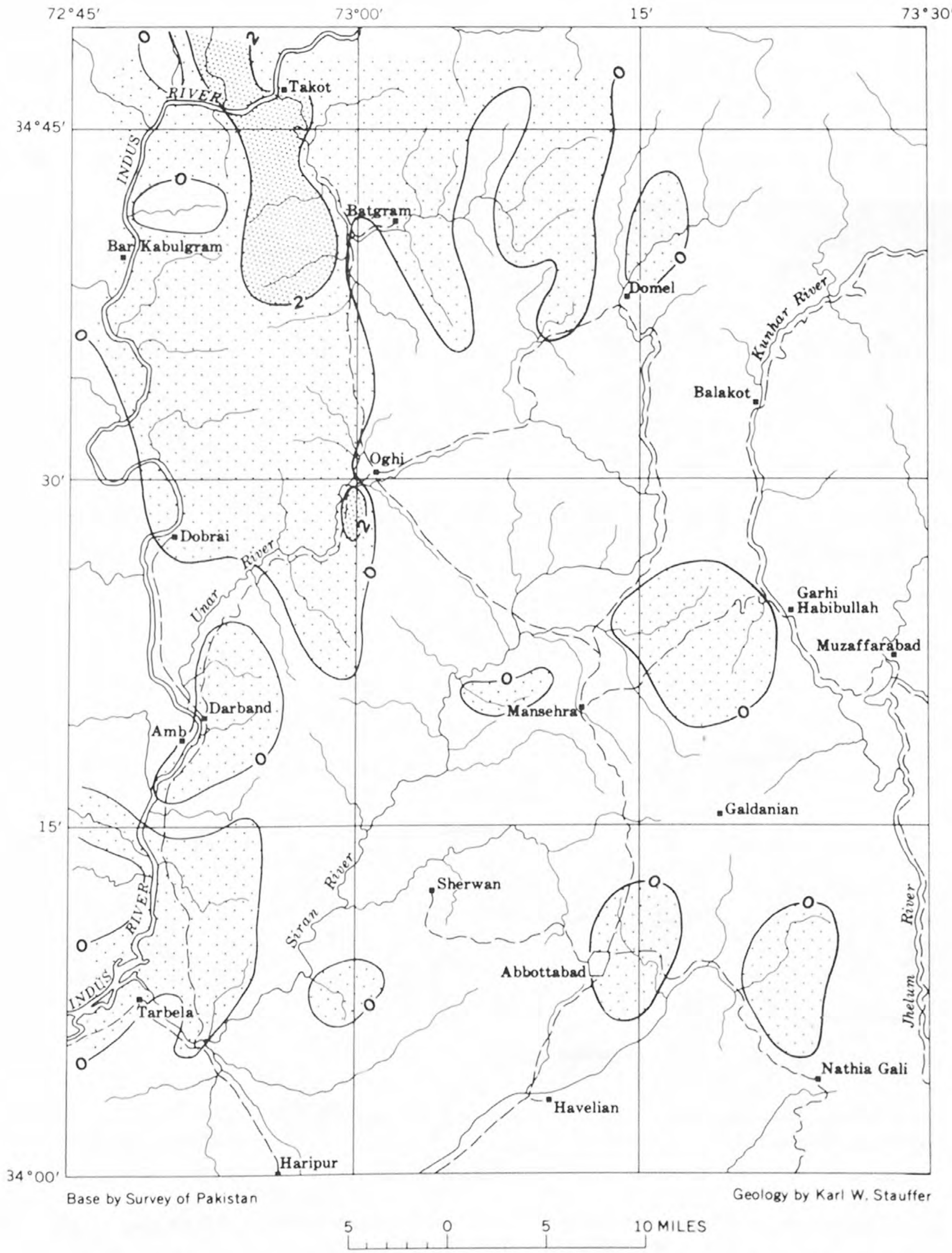

Figure 19.—Distribution of monazite as percent of heavy-mineral samples from southern Hazara District, Pakistan.

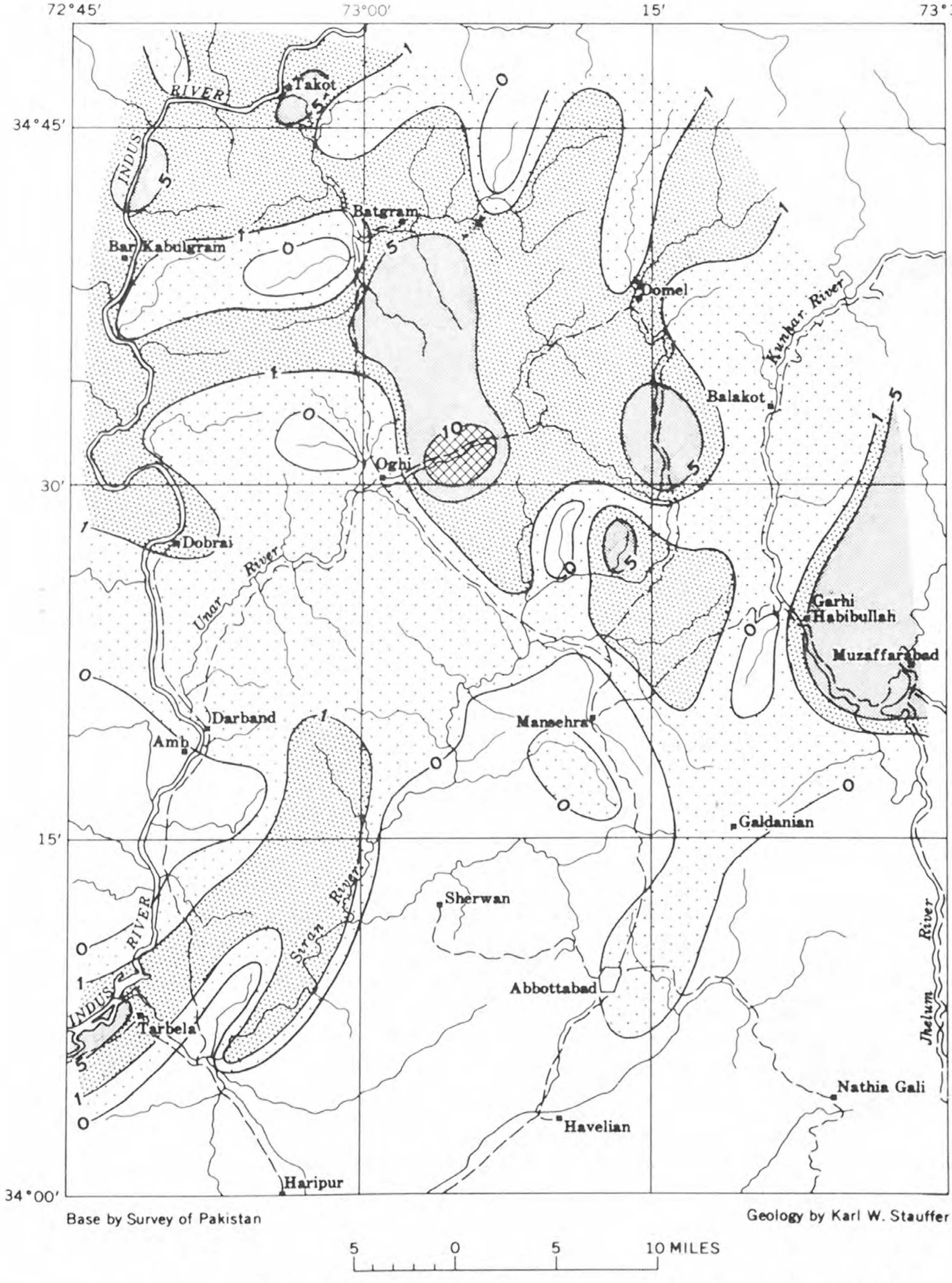

Figure 20.—Distribution of scheelite as grains per gram of heavy-mineral samples from southern Hazara District, Pakistan.

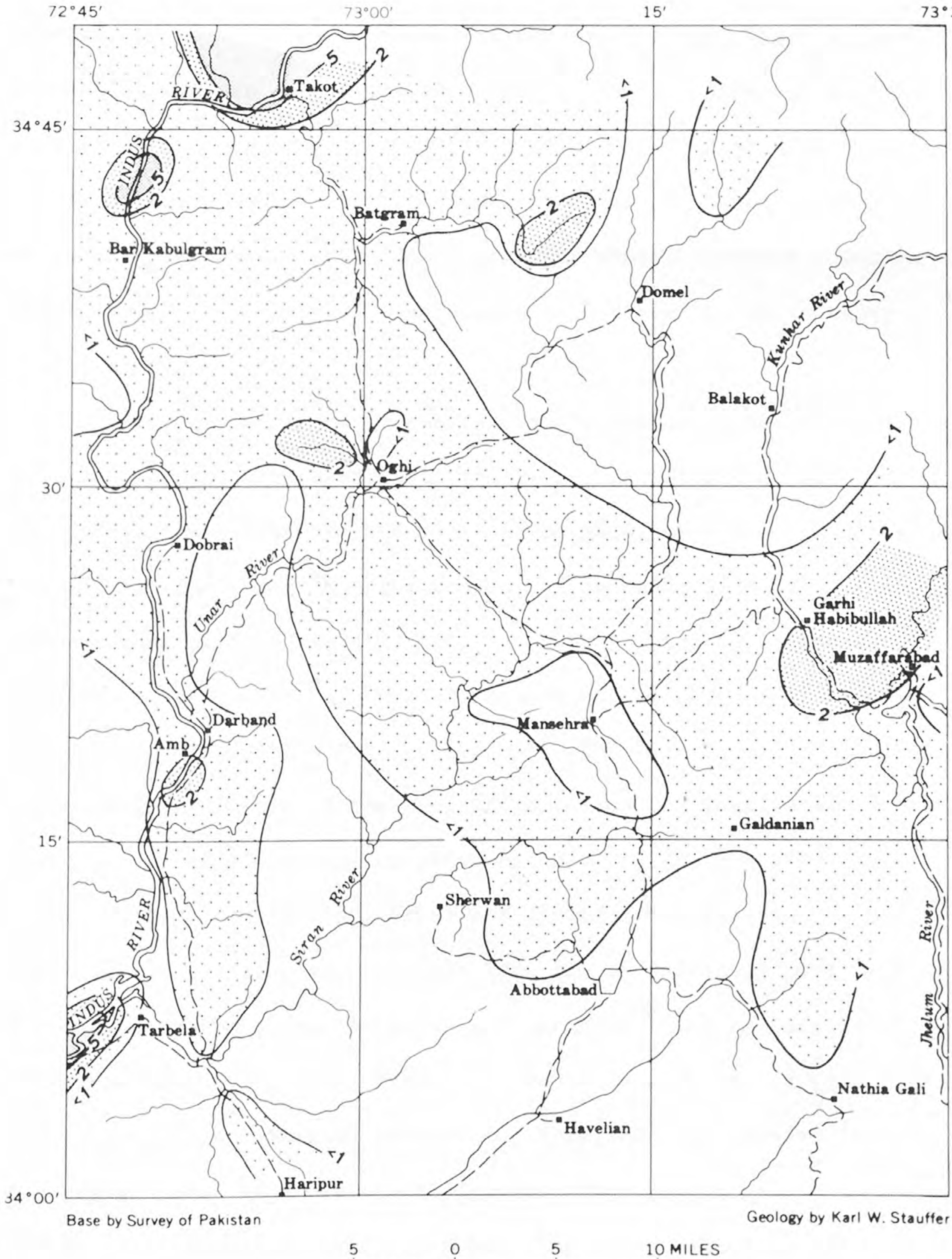

Figure 21.—Distribution of percent equivalent uranium content of heavy-mineral samples from southern Hazara District, Pakistan, after removal of magnetite.

The index minerals in order of increasing metamorphic grade are chlorite, brown biotite, almandine garnet, staurolite, kyanite, and sillimanite (Turner and Verhoogen, 1960, p. 491). As one progresses from a zone of lower metamorphic grade into one of higher grade, the percent of low-grade metamorphic index minerals should decrease and the higher grade metamorphic index minerals should increase. Such a change in the mineralogy of the rocks should be reflected in heavy-mineral sand samples.

To test whether there is any systematic change of the metamorphic facies in the southern Hazara District, the percentages of the common metamorphic index minerals were plotted on maps and contoured (figs. 4 through 9). The major chlorite concentration appears to be in the south-central part of the area (fig. 4). Brown biotite is found principally in the central area of the map and in some smaller areas farther north (fig. 5). Both garnet and staurolite appear mostly in the north-central part of the area (figs. 6 and 7); kyanite and sillimanite occur largely in the northernmost part (figs. 8 and 9).

These maps indicate a general but definite increase in the metamorphic grade of the heavy minerals from the stream sands in a north-northwest direction; this increase very probably is a reflection of a similar metamorphic grade increase in the rocks exposed in this area. This trend emerges clearly, despite the fact that the exposed rocks in the area are both metamorphic and igneous (fig. 2).

Field observations since then have indicated a similar gradual increase in the metamorphic grade of the rocks towards the northwest.

Volcanic materials

Two materials of volcanic origin, oxyhornblende and glass, were seen in small amounts in the Hazara heavy-mineral sand samples (fig. 10).

Oxyhornblende, which is readily identified by its dark color, pleochroism, very small extinction angle, and relatively high birefringence, is present in five samples, the quantity ranging from a trace to 2 percent. Its distribution is scattered and irregular, but three of the samples come from the area near the town of Mansehra where basaltic dikes are common.

Glass, apparently of volcanic origin, is present in nine samples, two of which also contained oxyhornblende. The distribution of the samples containing glass is also irregular.

It is possible that the oxyhornblende and glass fragments are second-cycle detrital materials derived from existing terrace or alluvial deposits. If so, the materials were derived from volcanic sources earlier when the present topography may have been somewhat different. Volcanic flows have been identified in the drainage areas of the Swat, Gilgit, and Hunza Rivers, farther north, and may be present elsewhere. Perhaps one or both of these materials originated in volcanic rocks some distance from the sample localities where they were found. The lack of adequate geologic information on most of the area north of the sampled region precludes the identification of the source of these volcanic materials.

MINERALS

Ilmenite

The ubiquitous accessory mineral ilmenite is the most common of all the heavy minerals found in the southern Hazara District. It was present in all samples taken, ranging in quantity from 5 to 88 percent of the heavy minerals and averaging 26 percent (fig. 11). It is generally, but not always, more abundant in samples collected from low-lying areas which contribute second-cycle detritus to the stream sands than in samples representing only detritus derived from bedrock. This relative abundance is further evidence of ilmenite's well-known resistance to decay, which permits the mineral to accumulate in placer deposits or as black sands, sometimes in sufficient quantity to be commercially mined as a source of titanium. Ilmenite is or has been extracted from beach sands in Brazil, Australia, Ceylon, and southern India (Emmons, 1940, p. 470).

In the southern Hazara District the only accumulations of sand sufficiently large to be of potential commercial interest are those along the banks of the Indus River. However, the ilmenite content of seven samples of these sands averaged only 15 percent of the heavy minerals, which by itself is not of commercial interest.

Magnetite

Magnetite was present in all heavy-mineral samples examined, ranging in quantity from a trace to 63 percent of the heavy minerals (fig. 12). The average magnetite content of the heavy minerals is 13 percent. The Indus River sands are conspicuous by the quantity of magnetite they contain; six Indus sand samples had an average magnetite content of 25 percent of the heavy minerals and one sample had a high of 58 percent. Samples from the low-lying area near Mansehra contained above average amounts of magnetite, probably as a result of magnetite's resistance to weathering, which permits it to survive relative to other less stable minerals.

The larger part of the magnetite in most samples probably originated as an accessory mineral in the Hazara rocks, but the unusually high percentages in the Indus River samples and in a few of the samples from its tributaries suggest the possibility that magnetite might exist in more concentrated form, such as magnetite-rich basic dikes or contact deposits, as have been found near Dammer Nissar in Chitral State, about 100 miles northwest of the southern Hazara District (Kidwai and Iman, 1958).

Magnetite-rich placer deposits are rather common in the world, but apparently only in Japan and to a lesser degree in New Zealand have they been mined for their iron content (Lindgren, 1933, p. 249; Japan Geol. Survey, 1960, p. 193). The separation of the magnetite from the sand is readily accomplished magnetically; the principal problem of utilizing placer deposits of magnetite is to find a deposit sufficiently large and free of titanium to be of economic value. Chemical tests for the titanium content of the magnetite in the Indus sands at Darband showed 2-1/2 to 3 percent titanium in the magnetite. Iron ore containing as much as 3 percent titanium can be readily handled in electric furnaces.

The Indus River annually transports about 450 million tons of suspended sediment downstream past the town of Darband (G. W. Caughran, Harza Engineering Co., personal communication). Of this quantity about 60 percent, or about 270 million tons, is fine sand, that is, particles whose diameter is greater than .044 mm. (C. M. Umar, Water and Power Development Authority, personal communication). The heavy minerals at Darband constitute about 1.5 percent of the Indus River sand, and the magnetite composes about 5 percent of the heavy minerals. Therefore, about 200,000 tons of magnetite are brought downstream past Darband each year. This quantity may be economical, particularly if the magnetite could be extracted as a byproduct of another activity. The proposed Tarbela Dam on the Indus River will form a collecting basin for all the fine sand and silt now carried downstream to the Indus plain. If the area behind the dam is cleaned of accumulated sand and silt by dredging or other means, the material thus removed could possibly be processed for magnetite. The magnetite could thus supplement other sources of iron ore for small steel plants.

Hematite

Hematite is present in minor amounts in most of the Hazara District samples (fig. 13). Only a few samples have more than a 3 percent hematite content.

One sample, however, stands out among all the rest because hematite constitutes 35 percent of the heavy minerals. This exceptionally high figure strongly suggests a hematite source of appreciable size within the drainage area represented by that sample. The percentage of hematite in this single heavy-mineral sample is sufficient to warrant further geological investigation of the area. It is, however, already known that this area, about 5 miles east-northeast of Abbottabad near Galdanian, contains deposits of hematitic iron ore.

Hydrous iron oxides

The hydrous iron oxides goethite and limonite are usually secondary products formed by the alteration of other iron-rich minerals. Most samples contain a few percent of these oxides, but this amount is not considered significant. The highest percentages of hydrous iron oxides were found in the samples east of Abbottabad (fig. 14), which also contained the maximum concentrations of hematite. The iron oxides are thus also related to the hematitic iron ore deposits east of Abbottabad and are probably largely derived by the weathering of hematite.

Pyrite

The iron sulfide pyrite is not in itself valuable, but, as it is commonly associated with other minerals of value, its presence may be an indication of mineralization.

The scattered pyrite in the heavy-mineral samples of the southern Hazara District (fig. 15) suggests that mineralization may have occurred in much of the area of this report. The areas with the highest percentages of pyrite in the heavy mineral samples are: 1) along the Indus River; 2) about 5 miles east of Abbottabad; 3) the Jhelum River, near Muzaffarabad. The first two areas contain several samples with 1 percent or more pyrite, and the third area shows a remarkably high content of pyrite, 9 percent, in a single sample. The above-average amounts of pyrite in these areas should be kept in mind later when the areas are geologically examined in detail. Much pyrite is associated with the gypsum unit of the Hazara formation in the Muzaffarabad area (J. A. Calkins, oral communication).

Zircon

Zircon is ubiquitous in the heavy-mineral samples from the southern Hazara District. It is not unusual to find zircon as a common heavy mineral in stream sands, but it is rare to find metamict zircon, including some of the hyacinth variety, as abundant as in these samples (figs. 16, 17 and 18). The terms "normal," "metamict," and "hyacinth" are here used in the sense described by Hutton (1950, p. 686-691).

Normal zircon is a common accessory mineral in most types of rocks and its presence is not significant. Metamict zircon, however, is of some interest because the metamict state is caused by the presence of the radioactive elements uranium and (or) thorium within the crystal lattice (Hutton, 1950, p. 693-695). Sample number 84, from a tributary of the Indus River in the northwestern part of the area, which contains the highest percentage of metamict zircon of any sample (7 percent) also has a considerably higher than normal radioactivity. This radioactivity is due at least in part to the uranium or thorium content of the metamict zircon.

The presence of small amounts of metamict zircon in most stream sands in the southern Hazara District suggests that the uranium and thorium contained in the mineral has a widespread but very diffuse distribution. The slightly higher concentrations of metamict zircon from samples in the central part of the area south of Mansehra (fig. 17) apparently are derived from both igneous and metamorphic rocks (fig. 2) and do not appear to be significant.

Monazite

The distribution of monazite, which generally contains rare earths, thorium, and uranium is shown on figure 19. The only area that contains appreciable monazite in the southern Hazara District is northwest of the Unar River. Virtually all the streams that drain this area contain 1 percent or more monazite in their heavy-mineral concentrates.

Monazite is a fairly common accessory mineral in gneisses, especially where pegmatites are present, and as the rocks in this northwest area are mostly gneisses, these are probably the source of most of the monazite. To be of economic value, monazite must be concentrated in appreciably greater quantities than the southern Hazara District sands contain.

Scheelite

The presence of scheelite in stream sands of the Hazara District has been known for a number of years, although the first published report did not appear until 1959 (Zeschke). Since then, further information has appeared (Danilchik and Tahirkheli, 1959; Davidson, 1962; Miller, 1962; Knapp and Bates, 1962; Tahirkheli, 1964).

The distribution of scheelite in the Hazara District heavy-mineral samples is shown on figure 20. The figure strikingly shows that scheelite is present in almost all streams draining igneous and metamorphic rocks. The sands of the Indus River clearly do not obtain all their scheelite from a single, perhaps distant, source, as has previously been suggested (Zeschke, 1961, p. 1250), but rather obtain some scheelite from almost all the tributary streams. Davidson (1962) and Mackay (1962) have also stated that Zeschke's suggestions were highly improbable. Scheelite appears to be a widely distributed mineral in the southern Hazara District.

The locations of samples having above average concentrations of scheelite extend roughly in a band between Muzaffarabad and Takot. All these concentrations are in the range of 6.0 to 8.4 grains of scheelite per gram of heavy minerals, except one. This sample, from about 3 miles east of Oghi, has 87 grains per gram of heavy minerals, a concentration more than 10 times greater than the next highest one. This figure very probably reflects a local abundance of scheelite within the drainage area of this particular stream. It is significant that three out of the four highest concentrations come from streams that drain the Oghi-Batgram-Battal area. About 4 miles north of Oghi, scheelite has been found in a loose granite-gneiss boulder at the foot of an east-trending ridge, and scheelite has more recently been found disseminated in the granite-gneiss northeast of Oghi (J.A. Calkins, oral communication).

The other samples having high scheelite concentrations are mostly from the large rivers, the Indus, Jhelum, Kunhar, and Kishanganga. Tahirkheli (1964) has visually estimated that there are about 0.02 ounces of scheelite per cubic yard of Indus River sand, but states that this estimate is probably too high. The general northwest-southeast distribution of samples with higher than average scheelite content may indicate a trend of rocks relatively richer in scheelite than those of the rest of the area. The source rock of the scheelite probably includes both the granite-gneisses and various metamorphic rocks, as scheelite is not uncommon in metamorphic rocks, especially in contact metamorphic zones rich in calcium.

Other minerals

Several other minerals of potential economic importance are present in the Hazara District heavy-mineral samples, but generally in quantities too small to warrant interest. These minerals include barite, bornite, gold, kyanite, muscovite, and sphalerite. The presence of these minerals is shown on table 1. Barite and sphalerite both occur only as a trace in a single sample. Barite showings have been found northeast of Tarbela and south of Havelian; sphalerite is not known in the Hazara District. Muscovite and kyanite are common minerals in the area, and their occurrences have been investigated by Ali, Calkins, and Offield (1964). Bornite was seen in trace amounts in three samples. It is found in minute quantities associated with pyrite and chalcopyrite veins in much of the Hazara District. Gold has been extracted from the Indus River sands for many years by local gold washers, but recent work by Miller (1962) and also by Tahirkheli (1964) indicates that its concentration is not sufficient to warrant commercial exploitation. Tahirkheli estimates that the 20 to 25 families engaged in gold washing produce about 14 troy ounces of gold per year, and that the average yield from specifically selected patches of Indus River alluvium is about 1.05 grains per cubic yard.

Conspicuous by their absence from all samples were cassiterite, uraninite, and uranothorite. All three of these minerals have been reported from the Indus River sands by other workers (Zeschke, 1959, p. 245; Ostle, 1959; Great Britain Geol. Survey, no date; Knapp and Bates, 1962, p. 2). Tahirkheli (1964) also reported them, but noted that they were extremely rare.

Cassiterite is optically quite similar to rutile, and some cassiterite may have been identified as rutile. A check of the rutile-rich samples, however, failed to reveal any cassiterite.

Uraninite is an opaque, black mineral that can be definitely identified only by means other than optical. It is quite possible that some grains of uraninite were counted as ilmenite. As the radioactivity of all the samples was measured, it is unlikely that uraninite, if present at all, makes up more than the most minute amount of any sample.

Uranothorite is a bright green mineral with a characteristic tetragonal prismatic habit and is readily identified by optical means alone. It is thus not possible that any grains of uranothorite were identified as another mineral. No uranothorite was present in any of the heavy-mineral samples examined.

The map of the equivalent uranium content of the heavy-mineral samples (fig. 21) shows that only samples from the Indus River have appreciable radioactivity, that is, more than 0.005% eU. The widespread distribution of samples with low radioactivity indicates that there is probably no concentrated source of radioactive minerals in the southern Hazara District.

CONCLUSIONS

The conclusions based on this study of heavy minerals from the stream sands of the Hazara District are:

1. The grade of metamorphism in the southern Hazara District increases toward the northwest.
2. Small amounts of volcanic material have been brought into the Hazara stream sands, probably from the northern regions.
3. Hematite, and to a lesser extent the hydrous iron oxides, in the heavy-mineral samples east of Abbottabad reflect the presence of the already known iron ore deposits of that area. Had these deposits been unknown, this heavy-mineral study would have found them.
4. The elements uranium and thorium are widespread in the area studied, but they are apparently present only in the minute quantities found in such minerals as metamict zircon and monazite.
5. The tungstate scheelite is found in appreciable quantities and may be of potential economic value in the Oghi-Batgram-Battal area.
6. Magnetite in sands of the Indus River could perhaps be a supplementary source of iron ore.
7. The results of this heavy-mineral study do not indicate the presence of potentially economic minerals other than hematite, scheelite, and magnetite in the southern Hazara District.

RECOMMENDATIONS

A detailed field investigation is needed to determine the source of the scheelite in the Oghi-Batgram-Battal area. Closely spaced heavy-mineral samples should be collected and examined for scheelite with a shortwave mineral light. Any scheelite concentrations could probably be located rapidly by following the traces of the mineral upstream. The source area of the scheelite should then be examined, if necessary at night with a mineral light, and its economic potential determined.

The feasibility of extracting magnetite from the Indus River sands in connection with the proposed Tarbela Dam should be investigated.

The extension of heavy-mineral sand-sampling programs to other areas of Pakistan is recommended as the most rapid initial method of surveying these areas for potential ore deposits.

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