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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE PINE RIDGE QUADRANGLE, MOFFAT COUNTY, COLORADO

[Report includes 27 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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CONTENTS

ILLUSTRATIONS

Illustrations--Continued

Illustrations--Continued

Illustrations--Continued

Illustrations--Continued

TABLES

INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Pine Ridge quadrangle, Moffat County, Colorado. This report was compiled to support the land-planning work of the Bureau of Land Management (BLM) and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. This investigation was undertaken by Dames & Moore, Denver, Colorado, at the request of the U.S. Geological Survey under contract number 14-08-0001-15789. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through February, 1979, was used as the data base for this study. No new drilling or field mapping was performed as part of this study, nor was any confidential data used.

Location

The Pine Ridge quadrangle is located in east-central Moffat County in northwestern Colorado approximately 4 miles (6 km) west of Craig along U.S. Highway 40, and 34 airline miles (55 km) north-northeast of Meeker, Colorado. With the exception of a few ranches, the area within the quadrangle is unpopulated.

Accessibility

U.S. Highway 40 crosses east-west through the southern part of the quadrangle connecting Craig to the east with the town of Maybell approximately 20 miles (32 km) to the west. An improved light-duty road follows Big Gulch from the west-central edge of the quadrangle to the northeastern corner. The remainder of the quadrangle is accessible by several other light-duty and unimproved dirt roads and trails.

Railway service for the Pine Ridge quadrangle is provided by the Denver and Rio Grande Western Railroad from Denver to the railhead at Craig. The railroad generally parallels U.S. Highway 40, terminating approximately 3 airline miles (5 km) east of the Pine Ridge quadrangle. It is the major transportation route for coal shipped east from northwestern Colorado (U.S. Bureau of Land Management, 1977).

Physiography

The Pine Ridge quadrangle lies in the southern part of the Wyoming physiographic province as defined by Howard and Williams (1972). The quadrangle is approximately 6 miles (10 km) northwest of the Williams Fork Mountains, 10 miles (16 km) northeast of the Axial Basin, and 50 miles (80 km) west of the Continental Divide (Tweto, 1976).

The landscape in the quadrangle is dominated by moderate to steep slopes cut by numerous gulches and narrow stream valleys. Altitudes in the quadrangle range from 7,186 feet (2,190 m) in the east-central part of the quadrangle to less than 6,240 feet (1,902 m) on Bogenschutz Creek in the southeastern corner of the quadrangle. Pine Ridge, located along the east-central edge of the quadrangle, rises to an altitude of over 7,000 feet (2,134 m).

The northern two thirds of the quadrangle is drained by Big Gulch and its tributaries. Big Gulch flows to the southwest forming a narrow valley from the northeast corner to the west-central edge of the quadrangle. It joins the Yampa River approximately 15 miles (24 km) to the southwest of the quadrangle. The southern third of the quadrangle is drained by Sand Spring Gulch and Pine Ridge Gulch. Sand Spring Gulch flows southwest and joins the Yampa River approximately 6 miles (10 km) to the southwest. Pine Ridge Gulch flows southeast, joining the Yampa River approximately 3 miles (5 km) to the southeast. All of the streams are intermittent and flow mainly in response to snowmelt in the spring.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Pine Ridge quadrangle area, with daily temperatures typically varying from 0° to 35°F (-18° to 2°C) in January and from 42° to 80°F (6° to 27°C) in July. Annual precipitation averages approximately 12 inches (30 cm). Snowfall during the winter months accounts for the major part of the precipitation in the area, but rainfall from thundershowers during the summer months also contributes to the total. Winds, averaging approximately 3 miles per hour (5 km per hour) are generally from the west, but wind directions and velocities vary greatly depending on the local terrain (U.S. Bureau of Land Management, 1977).

The predominate vegetation in the Pine Ridge quadrangle is sagebrush. The flatter areas, along Pine Ridge Gulch, Big Gulch, and the North Fork of Big Gulch in the southeastern, northeastern and northwestern corners of the quadrangle, respectively, are utilized for cropland (U.S. Bureau of Land Mangement, 1977).

Land Status

The Pine Ridge quadrangle lies along the western edge of the Yampa Known Recoverable Coal Resource Area (KRCRA). Approximately half of the quadrangle, including areas in the northern, southwestern, and southeastern parts of the quadrangle, lie within the KRCRA. The Federal government owns the coal rights for approximately 88 percent of this area as shown on plate 2. There are no active coal leases within the KRCRA in this quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area in which the Pine Ridge quadrangle is located was reported by Emmons (1877) as part of a survey of the Fortieth Parallel. The decision to build a railroad into the region stimulated several investigations of coal between 1886 and 1905, including papers by Hewett (1889), Hills (1893), and Storrs (1902). Fenneman and Gale (1906), in a geologic report on the Yampa Coal Field, included a description of the geology and coal occurrence in the Pine Ridge quadrangle. Gale (1910) described the coal fields of northwestern Colorado and northeastern Utah, including this quadrangle. Hancock (1925) described the geology and coal resources of the area south of the Pine Ridge quadrangle. Bass and others (1955) compiled a report on the geology and mineral fuels of parts of Routt and Moffat counties.

Tweto (1976) compiled a generalized regional geologic map which included the Pine Ridge quadrangle. Brownfield (1976) reported on reconnaissance drilling in the Yampa coal field by the U.S. Geological Survey during 1976. Brownfield and Prost (no date) compiled unpublished drill hole, coal outcrop, and geologic data for the Pine Ridge quadrangle.

Stratigraphy

The rock formations cropping out in the Pine Ridge quadrangle range in age from Late Cretaceous to Miocene and include the coal-bearing Lance and Fort Union Formations. The Williams Fork Formation of the Mesaverde Group also contains coal in the subsurface at depths less than 3,000 feet (914 m) below the ground surface.

The Late Cretaceous-age Iles and Williams Fork Formations of the Mesaverde Group occur in the subsurface of the quadrangle. The Trout Creek Sandstone Member, at the top of the Iles Formation, ranges in thickness from approximately 35 to 80 feet (11 to 24 m) where measured in the oil and gas wells drilled in the quadrangle, and typically consists of white, fine-grained thick-bedded to massive sandstone. The top of the Trout Creek Sandstone Member forms the contact between the Iles Formation and the conformably overlying Williams Fork Formation (Hancock, 1925; Bass and others, 1955).

The Williams Fork Formation ranges in thickness from approximately 1,450 to 1,700 feet (442 to 518 m) where measured in the oil and gas wells drilled in the quadrangle. The Williams Fork Formation consists of alternating brown to white, massive fine-grained sandstone, sandy shale, carbonaceous shale, and coal beds (Hancock, 1925). A prominent sandstone known as the Twentymile Sandstone Member is often present in the Williams Fork Formation. Coal beds below the Twentymile Sandstone Member are included in the Middle Coal Group, while coal beds above the member are in the Upper Coal Group (Fenneman and Gale, 1906). However, the Twentymile Sandstone Member was not identified in the oil and gas wells drilled in this quadrangle and Whitley (1962) indicates that it pinches out east of the quadrangle. Hancock (1925) was unable to trace the member past sec. 36, T. 6 N., R. 93 W., in the Horse Gulch quadrangle to the southwest, but he did infer it to crop out as far as the northwestern margin of the Horse Gulch quadrangle. Because the exact location of the top of the Middle Coal Group is unknown, the authors have arbitrarily designated the 700 feet (213 m) of coal-bearing rocks above the base of the Williams Fork Formation as the Middle Coal Group, and the remainder of the formation as the Upper Coal Group.

The Lewis Shale of Late Cretaceous age conformably overlies the Williams Fork Formation and crops out in the southeastern corner of the quadrangle (Brownfield and Prost, no date). It consists of dark-gray shale interbedded with sandstone (Hancock, 1925) and ranges in thickness from approximately 2,075 to 2,120 feet (632 to 646 m) where measured in the oil and gas wells drilled in the quadrangle.

The Fox Hills Sandstone of Late Cretaceous age intertongues with the underlying Lewis Shale and the overlying brackish-water and fluviatile sandstone and shale of the Lance Formation (Haun, 1961). It consists of grayish-white to gray, fine-grained massive resistant sandstone interbedded with shaly sandstone, gray sandy shale and gray papery shale (Dorf, 1942; Bass and others, 1955). It is approximately 90 to 180 feet (27 to 55 m) thick where measured in the oil and gas wells drilled in the quadrangle. The top of the Fox Hills Sandstone was mapped as the base of the Lance Formation by Brownfield and Prost (no date).

The Lance Formation of Late Cretaceous age crops out in a wide northwest-trending band across the central part of the quadrangle (Brownfield and Prost, no date), and conformably overlies the Fox Hills Sandstone. It consists of light-buff and light-tan, soft fine-grained sandstone, gray shale and coal (Bass and others, 1955) and ranges in thickness from approximately 660 to 970 feet (201 to 296 m) where measured in the oil and gas wells drilled in the quadrangle.

The Fort Union Formation of Paleocene age unconformably overlies the Lance Formation and crops out in a wide northwest-trending band across the central and northwestern parts of the quadrangle (Brownfield and Prost, no date). The total thickness of this formation is unknown in this quadrangle, but as much as 1,250 feet (381 m) of the formation may have been penetrated by the Great Western Drilling Company No. 1 Beckett well in sec. 6, T. 7 N., R. 91 W. It consists of a basal conglomerate and interbedded brown sandstone, gray shale, and coal beds (Bass and others, 1955).

The Wasatch Formation of Eocene age unconformably overlies the Fort Union Formation and crops out in the northeastern corner of the quadrangle (Brownfield and Prost, no date). It consists of coarse brown sandstone interbedded with gray and red clay shale (Bass and others, 1955). Information is not available on the total thickness of the Wasatch Formation in this quadrangle; however, it is estimated to be about 1,000 feet (305 m) thick.

The Browns Park Formation of Miocene age unconformably overlies older formations over much of the quadrangle (Brownfield and Prost, no date). According to Sears (1924), the Browns Park is at least 1,200 feet (366 m) thick in northwestern Colorado, but its total thickness in this quadrangle is unknown. It consists primarily of massive soft sandstone and hard calcareous sandstone, siltstone, claystone, and loosely consolidated eolian tuffaceous sandstone with conglomeraate beds at its base (Bergin, 1959; Tweto, 1976).

Holocene deposits of alluvium cover the stream valleys of Big Gulch, Sand Spring Gulch, Pine Ridge Gulch, Bogenschutz Creek, and the North Fork of Big Gulch (Brownfield and Prost, no date).

The Late Cretaceous formations exposed in the Pine Ridge quadrangle accumulated close to the western edge of a Late Cretaceous epeirogenic seaway which covered part of the western interior of North America. Several transgressive-regressive cycles caused the deposition of a series of offshore-marine, shallow-marine, marginal-marine, and non-marine sediments in the Pine Ridge quadrangle area (Ryer, 1977).

The interbedded sandstone, shale, and coal of the Mesaverde Group were deposited as a result of minor changes in the position of the shoreline. Near-shore marine, littoral, brackish tidal, brackish and fresh water supratidal, and fluvial environments existed during the deposition of the Williams Fork Formation. The Trout Creek Sandstone Member of the Iles Formation was deposited in a shallow-marine and near-shore environment. The lenticular coal beds of the Middle and Upper Coal Groups were generally deposited in environments associated with fluvial systems, such as back-levee and coastal plain swamps, inter-channel basin areas, and abandoned channels (Konishi, 1959; Kucera, 1959).

Deposition of the Lewis Shale marked a landward movement of the sea. The marine sediments of the Lewis Shale were deposited in water depths ranging from a few tens of feet to several hundred feet until a regional uplift west of the Yampa Basin area caused a regression of the sea and ended the deposition of the Lewis Shale in the area (Kucera, 1959).

The Fox Hills Sandstone represents transitional and nearshore-marine depositional environments between the deeper-water marine environment of the Lewis Shale and the lagoonal and continental environments of the Lance Formation. Deposition of the Fox Hills Sandstone occurred in shallow-marine, barrier bar, beach, estuarine and tidal channel environments (Weimer, 1959 and 1961).

As the sea regressed, the sediments in the Pine Ridge quadrangle area became increasingly terrestrial. The shale, sandstone, and coal deposited as the Lance Formation were formed in estuarine, marsh, lagoonal, and coastal swamp environments (O'Boyle, 1955; Weimer, 1959 and 1961).

After the final withdrawal of the Cretaceous sea, thick sections of detrital material, eroded from older deposits, were deposited as the coarse conglomerate and sandstone of the Fort Union Formation. The shale, sandstone, and coal of the Fort Union Formation were deposited in stream, flood-plain, and swamp environments (Beaumont, 1979). The coal beds that have wide areal extent were deposited near the seaward margins of the non-marine environments, probably in large brackish-water lagoons or swamps. Coals of limited areal extent were generally deposited in environments associated with fluvial systems, such as back-levee and coastal-plain swamps, interchannel basin areas and abandoned channels (Konishi, 1959; Kucera, 1959).

Depositional environments fluctuated between fluvial and lacustrine during the Eocene age when the Wasatch Formation was deposited (Picard and McGrew, 1955).

The Miocene-age Browns Park Formation was deposited after a long period of non-deposition and erosion. The coarse conglomeratic nature of the base of the Browns Park Formation and the fine wind-blown tuffaceous sands of the upper part of the formation suggest that it was deposited during a time when the climate of the region was changing from one of relatively high rainfall to one of semiaridity, such as is found in the region today (Carey, 1955).

Structure

The Yampa KRCRA lies in the southern extension of the Washakie/Sand Wash structural basin of south-central Wyoming. The basin is bordered on the east by the Park Range, approximately 49 miles (79 km) east of the Pine Ridge quadrangle, and on the southwest by the Axial Basin anticline approximately 12 miles (19 km) southwest of the quadrangle (Tweto, 1976).

The east-west-trending Lay syncline lies in the southern part of the quadrangle. The strata in the northern part of the quadrangle generally dip north-northeast. Brownfield and Prost (no date) have mapped ten faults in the Pine Ridge quadrangle. The largest two cut the coal beds in the northern half of the quadrangle. Most of the faults strike northwest to west-northwest, but three in the southeast quarter of the quadrangle strike north-northeast.

The structure contour maps of the isopached coal beds are based on a regional structure contour map of the Lance-Fort Union contact by Brownfield and Prost (no date), and it is assumed that the structure of the coal beds in the Fort Union Formation nearly duplicates that of the contact. Modifications were made where necessary in accordance with outcrop and drill-hole data.

COAL GEOLOGY

Numerous coal beds in the Williams Fork, Lance, and Fort Union Formations have been identified in the Pine Ridge quadrangle. The coal beds are generally thin, lenticular, and limited in areal extent, although several beds in the Fort Union Formation tend to persist over larger areas and extend into adjacent quadrangles. None of the coal beds are formally named, but the coal beds exceeding Reserve Base thickness (5 feet or 1.5 meters) have been given bracketed numbers for identification purposes in this quadrangle. In instances where coal beds greater than Reserve Base thickness are measured at one location only and cannot be correlated, they are treated as isolated data points (see Isolated Data Points section of this report).

Dotted lines shown on some of the derivative maps represent a limit of confidence beyond which isopach, structure contour, overburden isopach, and areal distribution and identified resources maps are not drawn because of insufficient data, even where it is believed that the coal beds may continue to be greater than Reserve Base thickness beyond the dotted lines.

Chemical analyses of coal.--Analyses of the coals in this and adjacent quadrangles are listed in table 1. In general, these analyses indicate that the coals in the Middle and Upper Coal Groups of the Williams Fork Formation are high-volatile C bituminous, and the coals in the Lance and Fort Union Formations are subbituminous B in rank on a moist, mineral-matter-free basis according to ASTM Standard Specification D-388-77 (American Society for Testing and Materials, 1977).

Coal Beds of the Williams Fork Formation

Coal beds in the Williams Fork Formation are divided into the Middle and Upper Coal Groups (Fenneman and Gale, 1906). The Middle Coal Group includes coal beds in the lower 700 feet (213 m) of the Williams Fork Formation, while the Upper Coal Group includes coal beds in the upper coal-bearing part of the formation. Coal beds in these two groups have been identified in two oil and gas test wells drilled near the southwest corner of the quadrangle.

The structure of the Middle and Upper Group coal beds is modified by the west-northwest-trending Williams Fork anticline in the adjacent Round Bottom quadrangle to the south and the Lay syncline in the southern part of this quadrangle. Two northwest-trending faults cut the coal beds in the area of the anticline.

Middle Coal Group

Ten Middle Group coal beds were isopached in this quadrangle and are shown on plates 4, 10, 14, 17, 20, and 23, and in figures 5, 9, 13, and 17. (All figures are attached to the end of this report.) The maximum measured thickness of the individual coal beds in this group range from 5.5 to 20.0 feet (1.7 to 6.1 m). Because the coal beds are identified in only two drill holes, the lateral control of each coal bed is poor and all the coal beds are inferred to thin away from the drill holes. All of the coal beds, except the MG[10] (i.e., Middle Coal Group, coal bed 10) coal bed, have been identified in the Round Bottom quadrangle to the south and have the same designation in that quadrangle. The coal beds generally do not contain rock partings, but partings ranging from 2.0 to 10.0 feet (0.6 to 3.0 m) in thickness have been identified in the MG[8] coal bed.

Upper Coal Group

Four Upper Group coal beds were isopached in the Pine Ridge quadrangle and are shown on figures 21, 25, 29, and 33. The maximum measured thicknesses of these coal beds range from 4.0 to 11.0 feet (1.2 to 3.4 m). Similar to the beds in the Middle Coal Group, the coal beds are inferred to thin away from the drill holes. Rock partings are not known to occur in any of the coal beds in this group. All of the coal beds extend into the Round Bottom quadrangle to the south where they have the same designations. One other coal bed, the UG[5], was identified at only one location and was treated as an isolated data point.

Coal Beds of the Lance Formation

Lenticular coal beds in the Lance Formation have been identified in the central-west and southeastern parts of the quadrangle. However, only two coal beds are known to exceed Reserve Base thickness and they are located in the central-west part of the quadrangle. Only one coal bed, the Lance [16], was isopached, and since the other coal bed was identified at one location only it has been treated as an isolated data point. In this area, the coal beds dip approximately 2° to 3° to the east-northeast and are cut by a west-northwest-trending fault. The Lance [16] coal bed ranges in thickness from 6.0 to 8.0 feet (1.8 to 2.4 m) where measured in two oil and gas wells drilled in secs. 3 and 10, T. 7 N., R. 92 W.

Coal Beds of the Fort Union Formation

Coal beds in the Fort Union Formation were identified in numerous drill holes and outcrops in the northern half of the quadrangle. The Fort Union coal beds in this area are generally thin and lenticular. They dip approximately 6° to 7° to the north-northeast and are cut by two northwest-trending faults. Thirteen Fort Union coal beds exceeding Reserve Base thickness were isopached in the area and are shown on plates 4, 7, 10, 14, 20, and 23. One additional Fort Union coal bed was identified at one location only and treated as an isolated data point.

Most of the coal beds extend over relatively small areas, ranging in maximum reported thicknesses from 5.1 to 8.5 feet (1.6 to 2.6 m) where measured along outcrops or in drill holes. An exception is the Fort Union [19] coal bed (plate 10) which is the thickest and most persistent coal bed in the Fort Union Formation in the Pine Ridge quadrangle. It ranges from 2.3 to 10.8 feet (0.7 to 3.3 m) in thickness where measured along the outcrop and from 6.5 to 17.0 feet (2.0 to 5.2 m) where penetrated by drill holes. A rock parting 8.6 feet (2.6 m) thick was reported in one of the drill holes.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 5 feet (1.5 m) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlations with other, better known coal beds. For this reason, isolated data point maps are included on a separate sheet (in U.S. Geological Survey files) for non-isopached coal beds. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle are listed in table 4.

COAL RESOURCES

Data from oil and gas wells and from drill holes, mine measured sections, and outcrop measurements (Brownfield and Prost, no date; Brownfield, 1976) were used to construct outcrop, isopach, and structure contour maps of the coal beds in the Pine Ridge quadrangle. The source of each indexed data point shown on plate 1 is listed in table 5.

Coal resources for Federal land were calculated using data obtained from the coal isopach and the areal distribution and identified resources maps. The coal bed acreage (measured by planimeter), multiplied by the average thickness of the coal bed and by a conversion factor of 1,770 short tons of coal per acre-foot (13,018 metric tons per hectare-meter) for subbituminous coal, or 1,800 short tons of coal per acre-foot (13,238 metric tons per hectare-meter) for bituminous coal, yields the coal resources in short tons of coal for each coal bed. Coal beds thicker than 5 feet (1.5 m) that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ somewhat from those stated in U.S. Geological Survey Bulletin 1450-B which call for a minimum thickness of 28 inches (70 cm) for bituminous coal and a maximum depth of 1,000 feet (305 m) for both subbituminous and bituminous coal.

Reserve Base and Reserve tonnages for the isopached coal beds are shown on the areal distribution and identified resources maps, and are rounded to the nearest 10,000 short tons (9,072 metric tons). Only Reserve Base tonnages (designated as inferred resources) are calculated for areas influenced by the isolated data points. Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 213.45 million short tons (193.64 million metric tons) for the entire quadrangle, including the tonnages for the isolated data points. Reserve Base tonnages in the various development potential categories for surface and subsurface mining methods are shown in tables 2 and 3.

Dames & Moore has not made any determination of economic recoverability for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn to coincide with the boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for a high development potential; 25 acres (10 ha), a moderate development potential; and 10 acres (4 ha), a low development potential; then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 200 feet (61 m) or less of overburden are considered to have potential for surface mining and were assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for surface mining of coal is shown on the following page:

$$MR = \frac{t_o\,(cf)}{t_c\,(rf)}$$

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short tons of recoverable coal:
0.911 for subbituminous coal
0.896 for bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate, and low development potential for surface mining methods are defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey.

Areas where the coal data is absent or extremely limited between the 200-foot (61-m) overburden line and the outcrop are assigned unknown development potential for surface mining methods. This applies to areas where coal beds 5 feet (1.5 m) or more thick are not known, but may occur, and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds prevents accurate evaluation of development potential in the high, moderate, and low categories. There are no areas influenced by isolated data points which contain coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 26. Of the Federal land areas having a known development potential for surface mining, 79 percent are rated high, 4 percent are rated moderate, and 17 percent are rated low. The remaining Federal lands within the KRCRA boundary in this quadrangle are classified as having unknown development potential for surface mining methods.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for subsurface mining methods include those areas where coal beds of Reserve Base thickness are between 200 and 3,000 feet (61 and 914 m) below the ground surface which have dips of 15° or less. Unfaulted coal beds lying between 200 and 3,000 feet (61 and 914 m) below the ground surface, dipping greater than 15°, are considered to have development potential for in-situ mining methods.

Areas of high, moderate, and low development potential for conventional subsurface mining are defined as areas underlain by coal beds at depths ranging from 200 to 1,000 feet (61 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m) below the ground surface, respectively.

Areas where the coal data is absent or extremely limited between 200 and 3,000 feet (61 and 914 m) below the ground surface are assigned unknown development potentials. This applies to the areas influenced by isolated data points and to those areas where coal beds of Reserve Base thickness are not known, but may occur. The areas influenced by isolated data points in this quadrangle contain approximately 5.70 million short tons (5.17 million metric tons) of coal available for subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 27. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 57 percent are rated high and 43 percent is rated moderate. The remaining Federal land within the KRCRA boundary is classified as having unknown development potential for conventional subsurface mining methods.

Based on criteria provided by the U.S. Geological Survey, coal beds of Reserve Base thickness dipping between 15° and 35°, regardless of tonnage, have low development potential for in-situ mining methods. Coal lying between the 200-foot (61-m) overburden isopach and the outcrop is not included in total coal tonnages available because it is needed for cover and containment in the in-situ process.

All of the Federal lands where the dip of the coal beds exceeds 15° are rated low for in-situ development potential because faults are present and only approximately 10.46 million short tons (9.49 million metric tons) of coal distributed through 12 different coal beds are believed to be available for in-situ mining. The remaining Federal lands within the proposed KRCRA boundary in this quadrangle are classified as having unknown development potential for in-situ mining methods.

Table 1. -- Chemical analyses of coals in the Pine Ridge quadrangle, Moffat County, Colorado.

Location	COAL BED NAME	Form of Analysis	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/Lb
NW¼ sec. 6, T. 5 N., R. 91 W., Wise Mine (George and others, 1937) from Round Bottom quadrangle	Middle Coal Group	A	13.3	33.5	45.8	7.4	0.5	-	-	-	-	-	10,510
		C	-	38.6	52.9	8.5	0.6	-	-	-	-	-	12,110
NW¼ SW¼ sec. 29, T. 6 N., R. 91 W., Haubrich Mine (George and others, 1937) from Round Bottom quadrangle	Upper Coal Group	A	17.8	30.4	48.0	3.8	0.5	-	-	-	-	-	10,340
		C	-	37.0	58.4	4.6	0.6	-	-	-	-	-	12,570
Sec. 32, T. 7 N., R. 90 W., Kimberley Mine (Fieldner and others, 1918) from Craig quadrangle	Lance Formation Kimberley	A	22.10	31.61	41.95	4.34	0.72	-	-	-	-	-	9,297
		C	-	40.58	53.85	5.57	0.92	-	-	-	-	-	11,934
Sec. 2, T. 7 N., R. 92 W., Seick Mine (Fieldner and others, 1918)	Fort Union (6)	A	23.26	29.59	40.02	7.13	0.65	-	-	-	-	-	8,867
		C	-	38.56	52.15	9.29	0.85	-	-	-	-	-	11,554

Form of Analysis: A, as received
C, moisture free

Note: To convert Btu/pound to kilojoules/kilogram, multiply by 2.326

Table 2. -- Coal Reserve Base data for surface mining methods for Federal coal lands (in short tons) in the Pine Ridge quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fort Union {30}	90,000	50,000	20,000	-	160,000
Fort Union {29}	10,000	-	-	-	10,000
Fort Union {28}	70,000	-	-	-	70,000
Fort Union {27}	40,000	20,000	100,000	-	160,000
Fort Union {26}	60,000	50,000	200,000	-	310,000
Fort Union {25}	120,000	50,000	330,000	-	500,000
Fort Union {24}	80,000	60,000	280,000	-	420,000
Fort Union {23}	20,000	10,000	50,000	-	80,000
Fort Union {22}	50,000	10,000	-	-	60,000
Fort Union {21}	40,000	30,000	90,000	-	160,000
Fort Union {19}	480,000	300,000	1,160,000	-	1,940,000
Fort Union {18}	280,000	90,000	670,000	-	1,040,000
Totals	1,340,000	670,000	2,900,000	-	4,910,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 3. -- Coal Reserve Base data for subsurface mining methods for Federal coal lands (in short tons) in the Pine Ridge quadrangle, Moffat County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Fort Union {27}	20,000	-	-	-	20,000
Fort Union {26}	50,000	-	-	-	50,000
Fort Union {25}	80,000	-	-	-	80,000
Fort Union {24}	150,000	-	-	-	150,000
Fort Union {23}	10,000	-	-	-	10,000
Fort Union {20}	1,060,000	1,860,000	-	-	2,920,000
Fort Union {19}	15,020,000	12,050,000	-	-	27,070,000
Fort Union {18}	430,000	-	-	-	430,000
Lance {16}	3,170,000	210,000	-	-	3,380,000
UG {10}	2,160,000	-	-	340,000*	2,500,000
UG {9}	2,430,000	5,670,000	-	1,030,000*	9,130,000
UG {4}	-	520,000	-	340,000*	860,000
UG {3}	-	6,260,000	-	210,000*	6,470,000
MG {15}	-	13,760,000	-	980,000*	14,740,000
MG {14}	-	21,820,000	-	3,410,000*	25,230,000
MG {13}	-	20,020,000	820,000	2,200,000*	23,040,000
MG {12}	-	1,430,000	-	-	1,430,000
MG {11}	-	10,100,000	1,560,000	70,000*	11,730,000
MG {10}	-	1,690,000	1,440,000	-	3,130,000

*Tonnages for coal beds dipping greater than 15 degrees.

Table 3. -- Continued. (Pine Ridge)

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
MG {8}	-	15,830,000	10,960,000	1,260,000*	28,050,000
MG {7}	-	2,630,000	1,090,000	-	3,720,000
MG {6}	-	10,960,000	10,610,000	280,000*	21,850,000
MG {2}	-	5,620,000	7,160,000	150,000*	12,930,000
MG {1}	-	2,280,000	1,450,000	190,000*	3,920,000
Isolated Data Points	-	-	-	5,700,000	5,700,000
Totals	24,580,000	132,710,000	35,090,000	16,160,000	208,540,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 4.--Descriptions and Reserve Base tonnages (in million short tons) for isolated data points

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages Surface	Reserve Base Tonnages Subsurface
UG[5]	Intex Oil Co. No. 1 Preece et. al.	sec. 29, T. 7 N., R. 92 W.	6.0 ft (1.8 m)	0	1.51
Lance [17]	Rainbow Resources, Inc. No. 1-26 Nottingham	sec. 26, T. 8 N., R. 92 W.	7.0 ft (2.1 m)	0	2.69
Fort Union[31]	Great Western Drilling Co. No. 1 Beckett	sec. 6, T. 7 N., R. 91 W.	6.0 ft (1.8 m)	0	1.50

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 5. -- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	Great Western Drilling Co.	Oil/gas well No. 1 Beckett
2	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
3	↓	Measured Section
4		Measured Section
5		Measured Section
6		Measured Section
7		Measured Section
8	Carter Oil Co.	Oil/gas well No. 1 Gov't
9	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
10	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-10-PR
11	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
12	↓	Measured Section
13		Measured Section
14		Measured Section
15		Measured Section
16		Measured Section
17		Measured Section
18	Pan American Petroleum Corp.	Oil/gas well No. 1 USA Thomas G. Dorough

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
19	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
20	↓	Measured Section
21	Tesoro Petroleum Co. and George Dolezal	Oil/gas well No. 1 Federal
22	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
23	Intex Oil Co.	Oil/gas well No.1 Preece et al
24	Buttes Gas and Oil Co.	Oil/gas well No. 1 Winder et al
25	Rainbow Resources Inc.	Oil/gas well No. 1-26 Nottingham
26	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
27	Rainbow Resources Inc.	Oil/gas well No. 1-29 Federal
28	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
29	↓	Measured Section
30	↓	Measured Section
31	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-9-PR
32	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
33	↓	Measured Section
34	↓	Measured Section

Table 5. -- Continued

Plate 1 Index Number	Source	Data Base
35	Brownfield and Prost, no date, U.S. Geological Survey, unpublished data	Measured Section
36	↓	Measured Section
37	↓	Measured Section
38	↓	Measured Section
39	↓	Measured Section
40	Brownfield, 1976, U.S. Geological Survey Open-File Report No. 76-817	Drill hole No. Y-12-PR

Page 3 of 3

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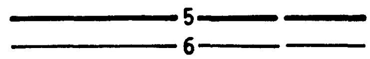
EXPLANATION



ISOPACHS - Showing thickness of coal, in feet. Long dashed where inferred; short dashed where projected beyond coal-bearing area. Isopach interval 1 foot for all coal beds except Middle Coal Group, coal bed [14], where isopach interval is 5 feet.

o 15.5

DRILL HOLE - Showing thickness of coal, in feet.

COAL BED SYMBOLS AND NAMES - Coal beds identified by bracketed numbers are not formally named, but are numbered for identification purposes in this quadrangle only.

TRACE OF FAULT - Bar and ball on downthrown side. Dashed where inferred or approximately located.

To convert feet to meters, multiply feet by 0.3048.

FIGURE 1. — Explanation for isopach maps.

EXPLANATION

5000
5100

STRUCTURE CONTOURS - Drawn on top of coal bed. Solid where vertical accuracy within 40 feet; long dashed where vertical accuracy possibly not within 40 feet. Contour interval 100 feet (31 m). Datum is mean sea level.

o 4715

DRILL HOLE - Showing altitude of top of coal bed, in feet.

COAL BED SYMBOLS AND NAMES - Coal beds identified by bracketed numbers are not formally named, but are numbered for identification purposes in this quadrangle only.

15°

SUBSURFACE MINING LIMIT - Showing areas where dips of coal beds are greater than 15° and subsurface mining by conventional methods is not considered feasible. Reserve Base tonnages are calculated beyond limit; Reserve tonnages are not. Arrow points toward area where dips are greater than 15°.

TRACE OF FAULT - Bar and ball on downthrown side. Dashed where inferred or approximately located.

SYNCLINE - Showing trace of axial plane.

ANTICLINE - Showing trace of axial plane.

To convert feet to meters, multiply feet by 0.3048.

FIGURE 2. — Explanation for structure contour maps.

page 32 follows

EXPLANATION

1400

OVERBURDEN ISOPACHS - Showing thickness of overburden, in feet, from surface to top of coal bed. Dashed where vertical accuracy possibly not within 40 feet. Isopach interval 200 feet (61 m).

o 1854

DRILL HOLE - Showing thickness of overburden, in feet, from surface to top of coal bed.

COAL BED SYMBOLS AND NAMES - Coal beds identified by bracketed numbers are not formally named, but are numbered for identification purposes in this quadrangle only.

TRACE OF FAULT - Bar and ball on downthrown side. Dashed where inferred or approximately located.

To convert feet to meters, multiply feet by 0.3048.

FIGURE 3. — Explanation for overburden isopach maps.

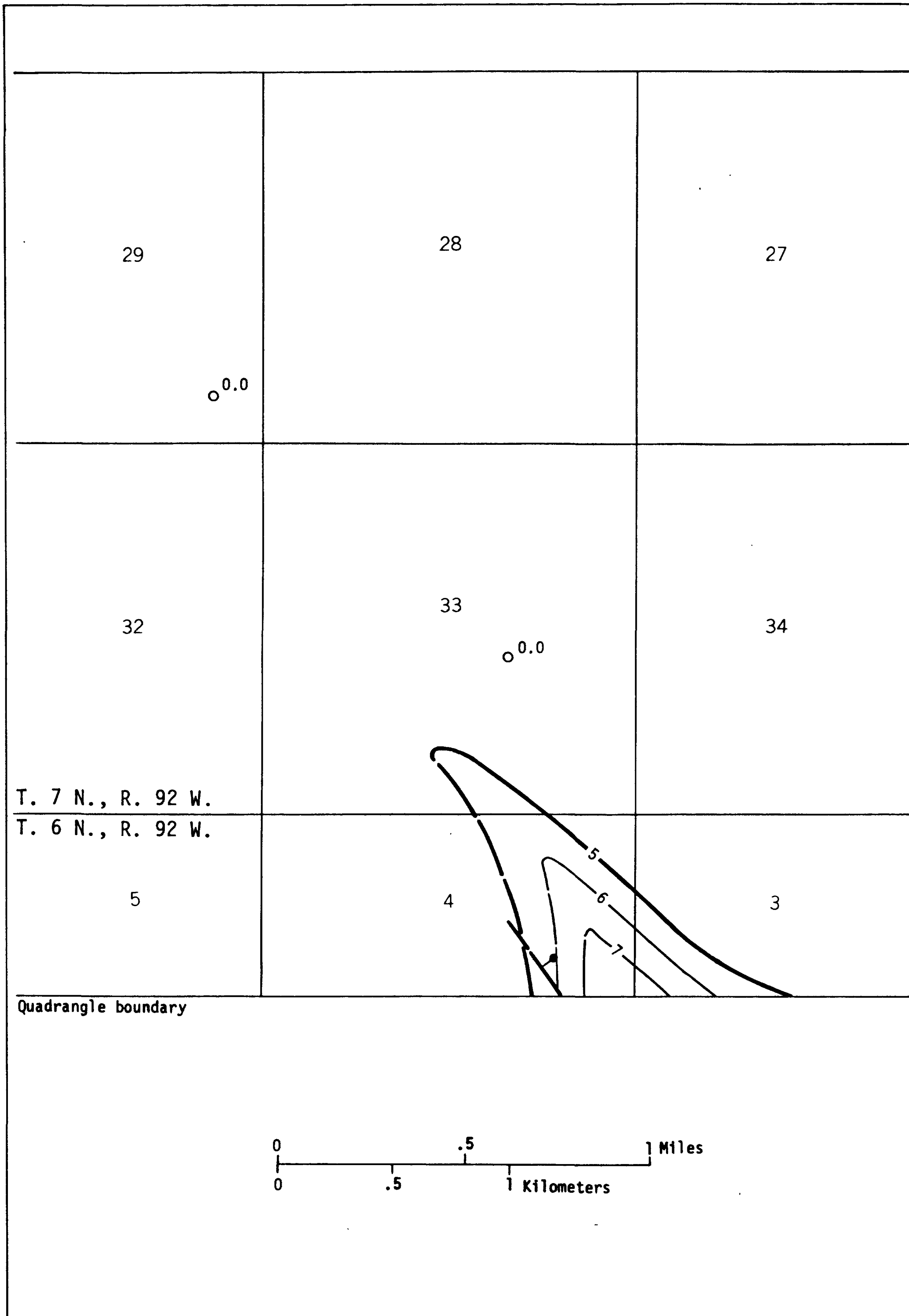


FIGURE 5. — Isopach map of the Middle Coal Group, coal bed [12].

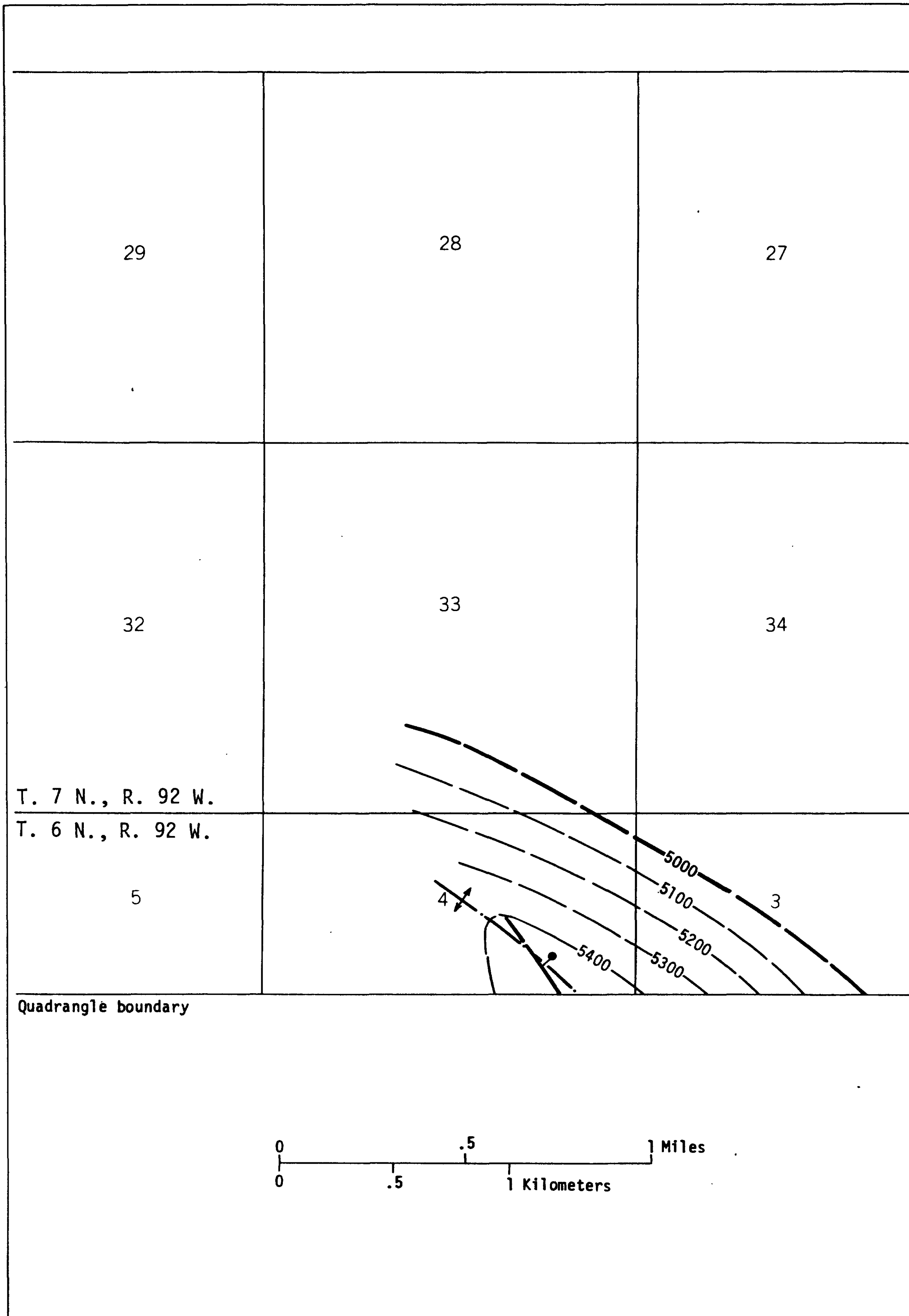


FIGURE 6. — Structure contour map of the Middle Coal Group, coal bed [12].

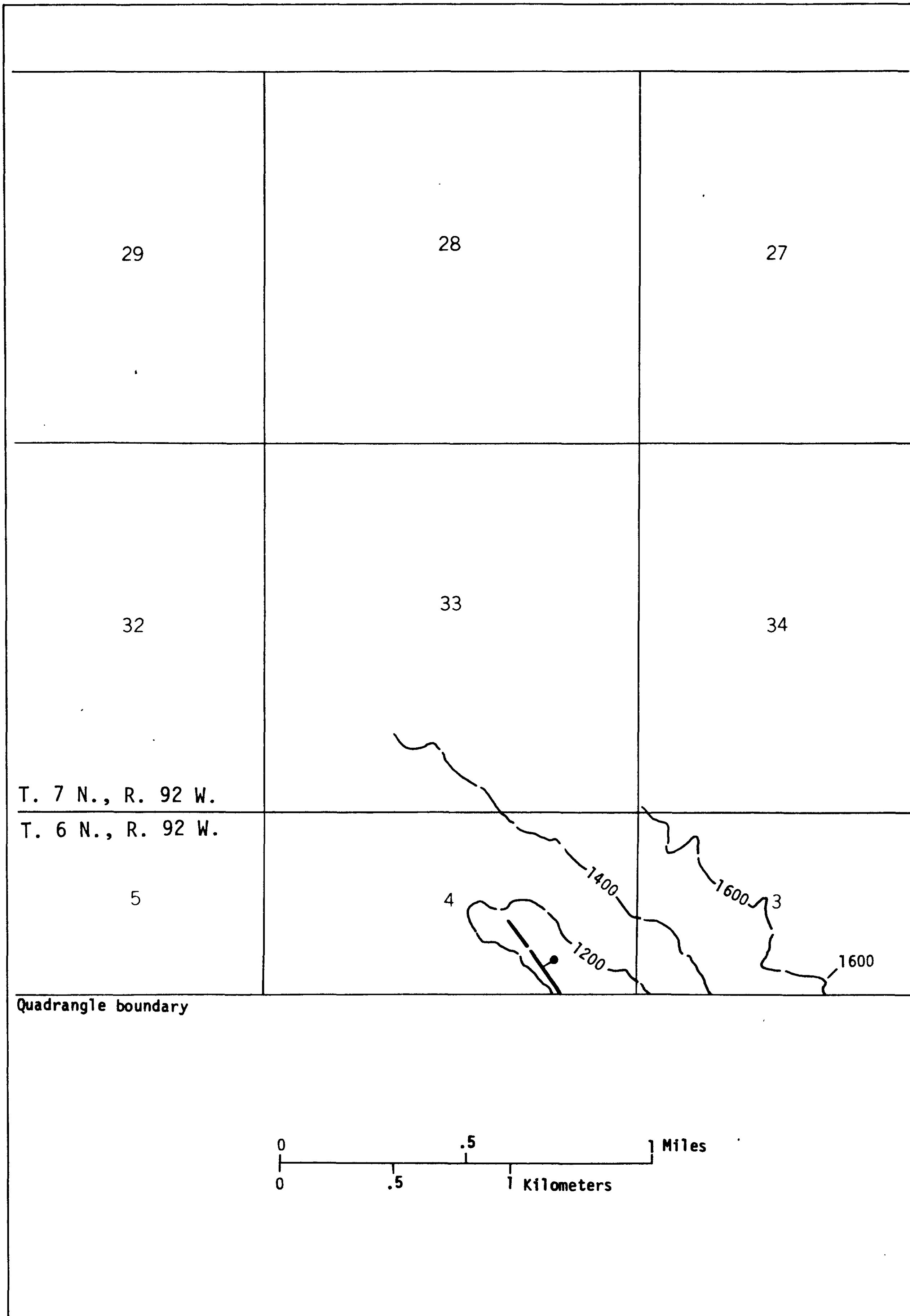


FIGURE 7. — Overburden isopach map of the Middle Coal Group, coal bed [12].

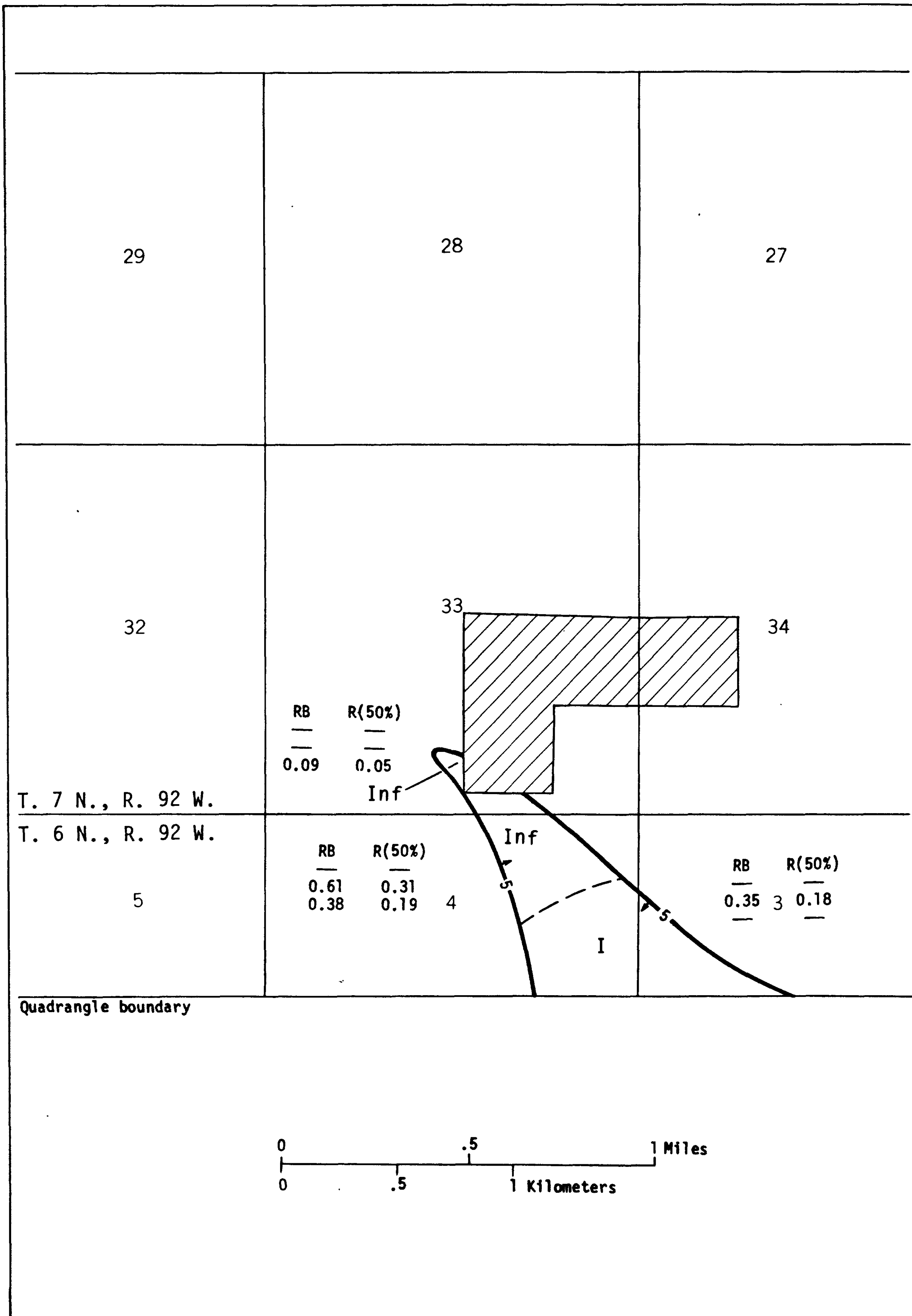


FIGURE 8. — Areal distribution and identified resources map of the Middle Coal Group, coal bed [12].

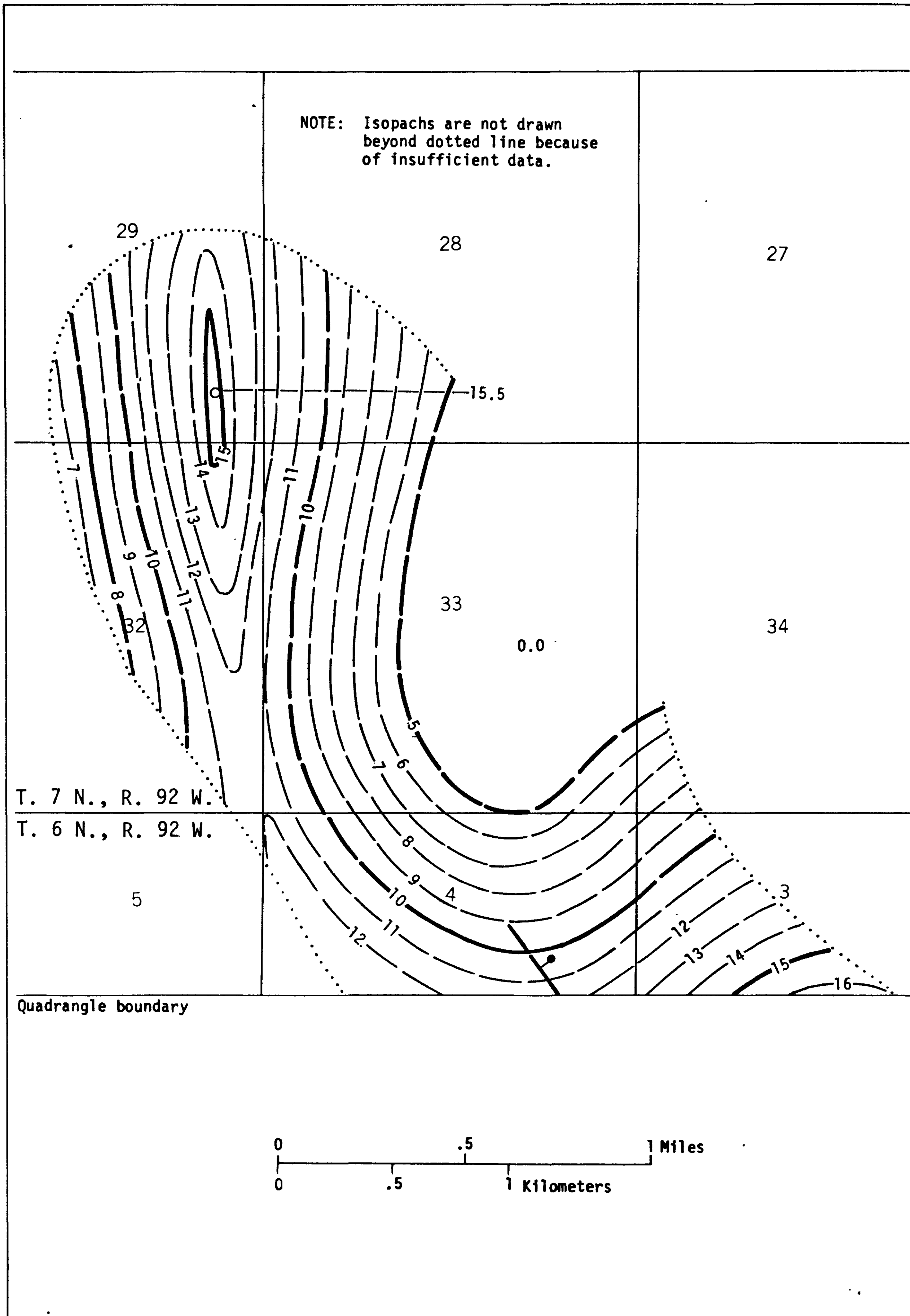


FIGURE 9. — Isopach map of the Middle Coal Group, coal bed [13].

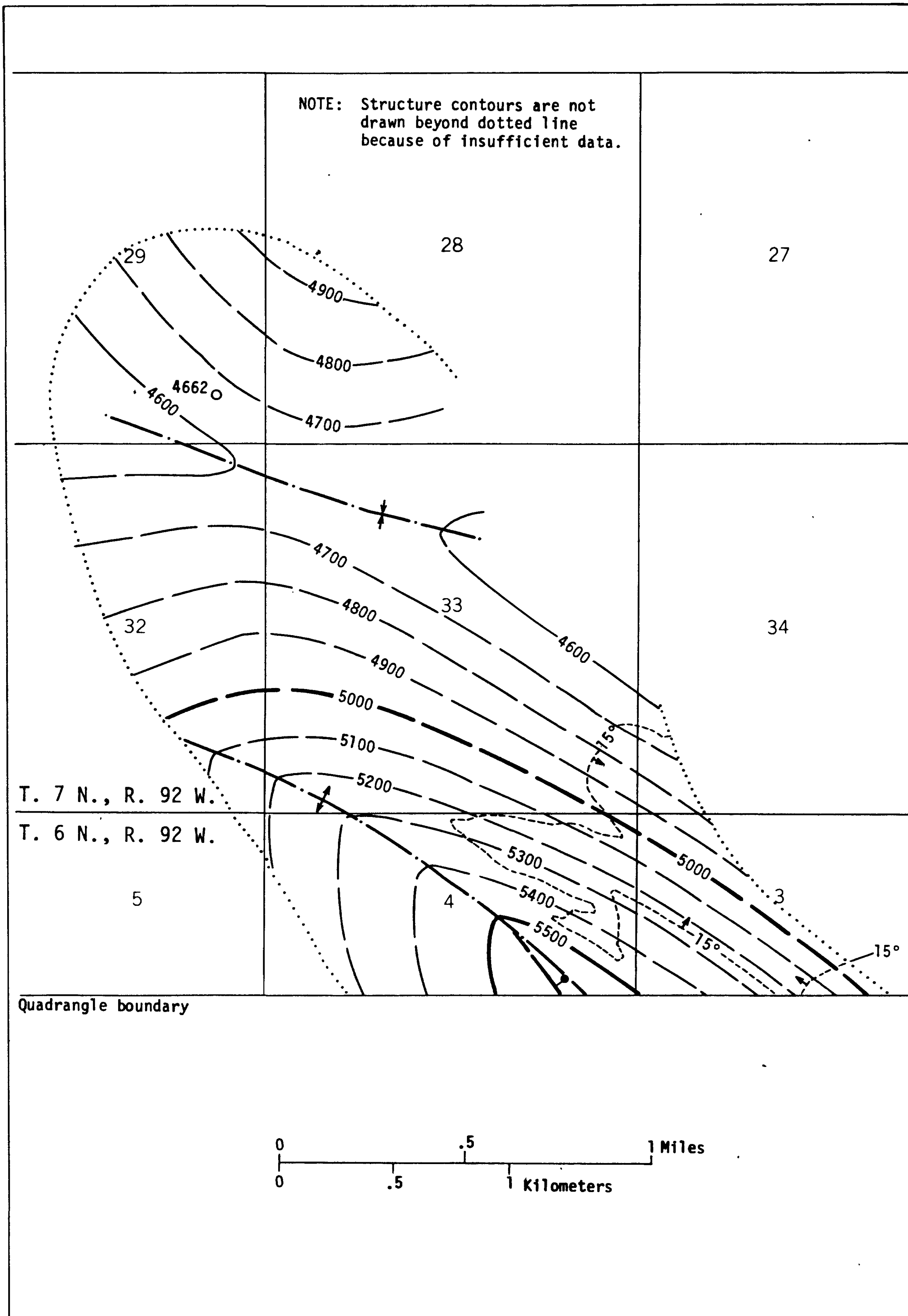


FIGURE 10. — Structure contour map of the Middle Coal Group, coal bed [13].

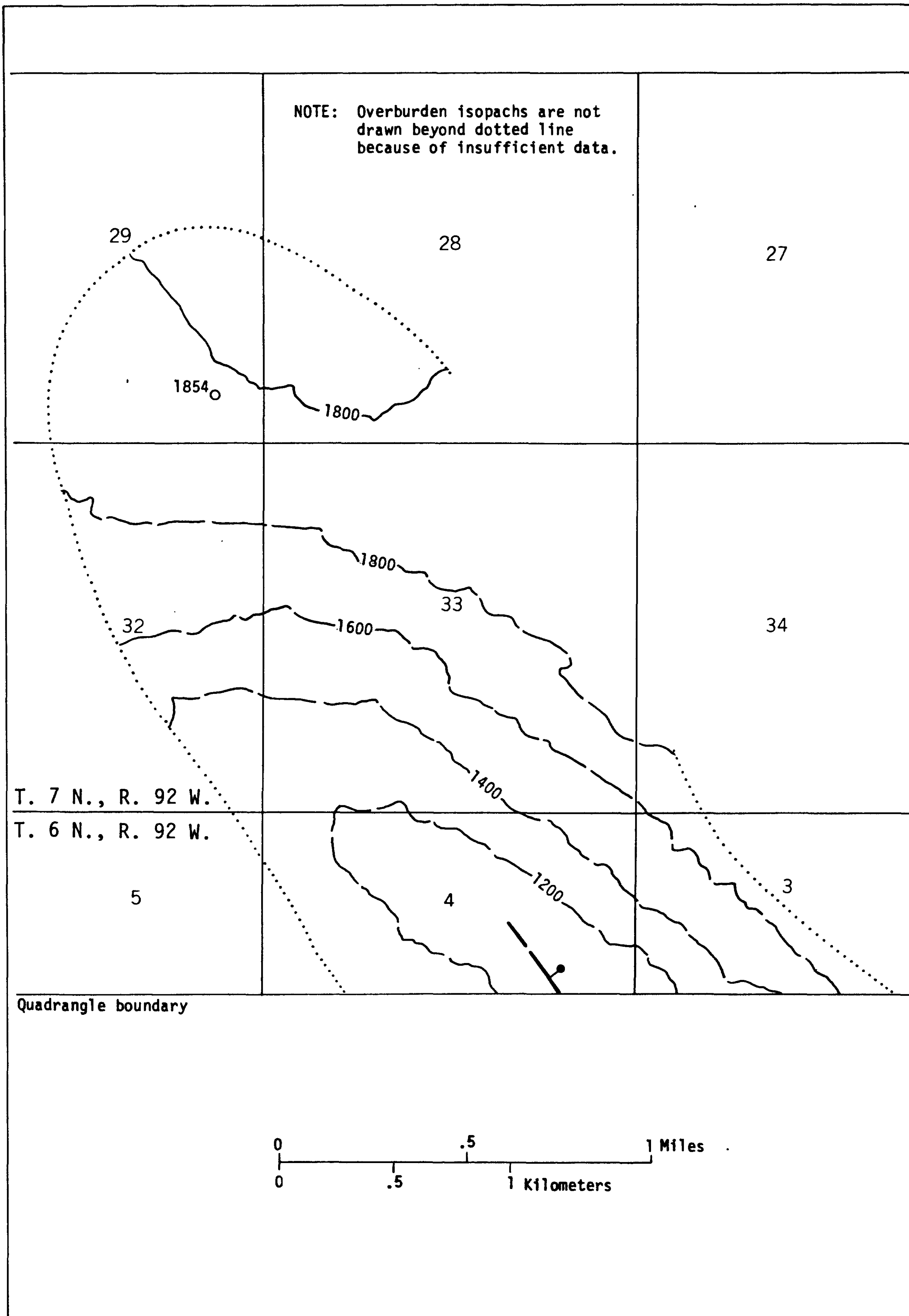


FIGURE 11. — Overburden isopach map of the Middle Coal Group, coal bed [13].

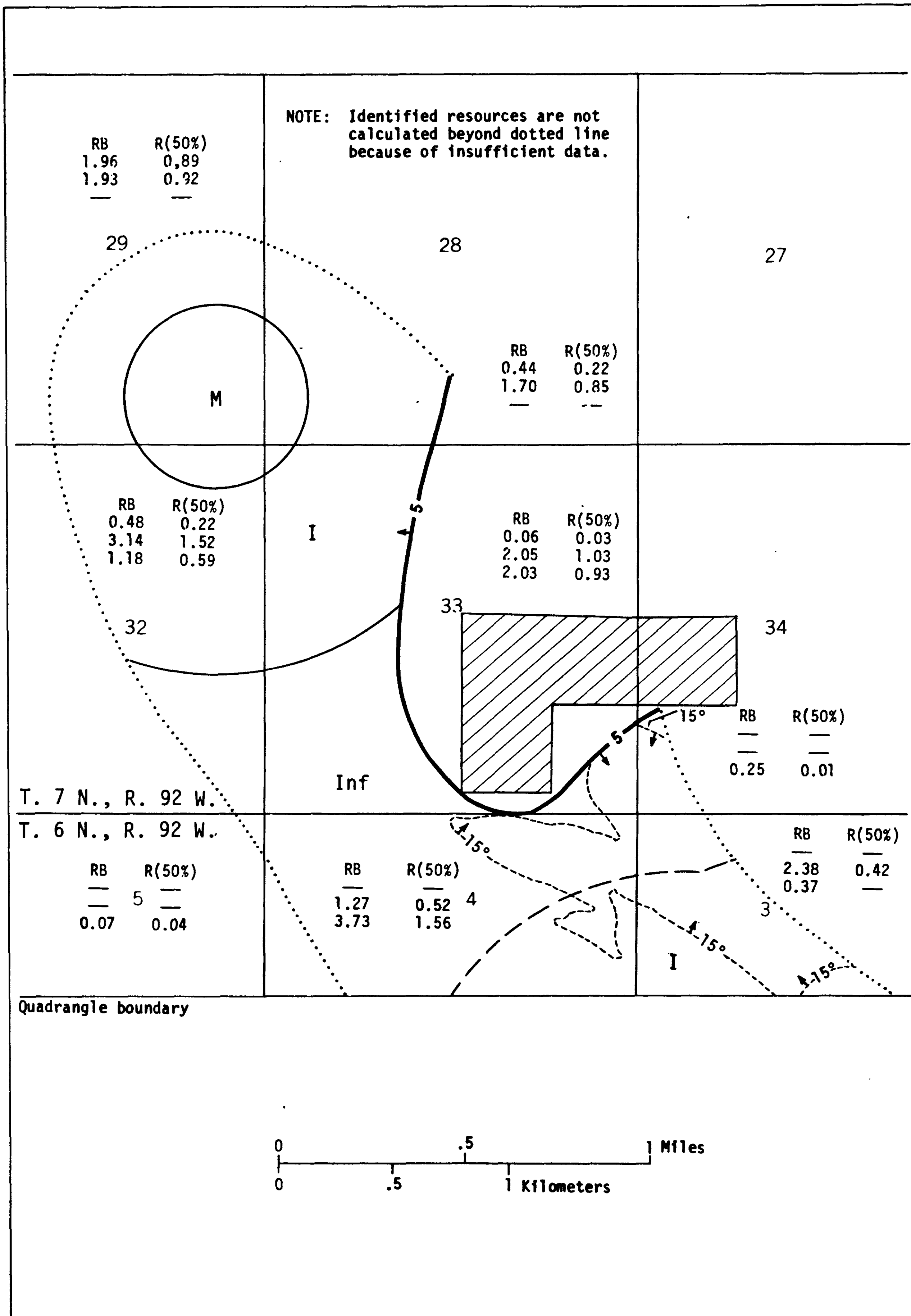


FIGURE 12. — Areal distribution and identified resources map of the Middle Coal Group, coal bed [13].

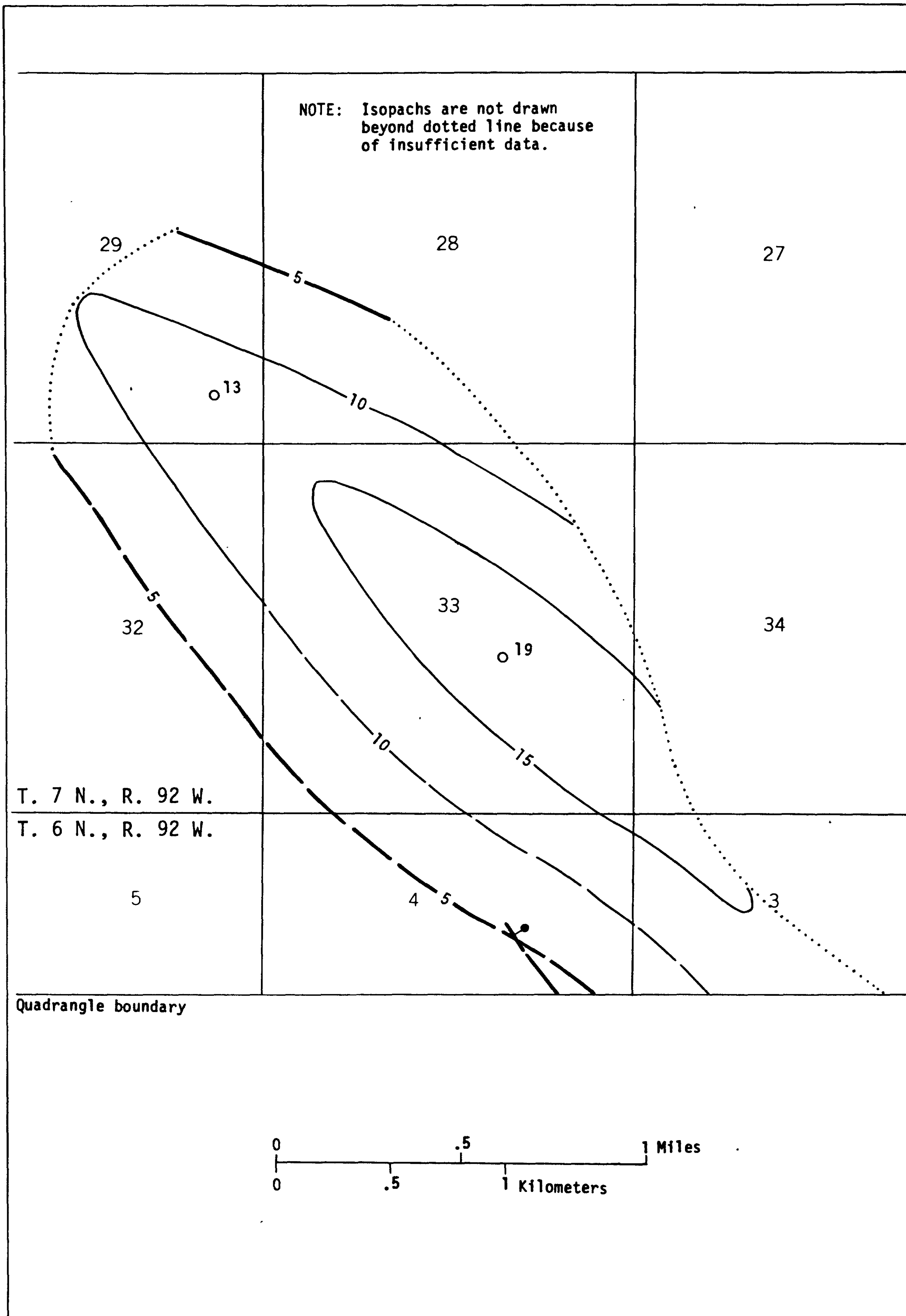


FIGURE 13. — Isopach map of the Middle Coal Group, coal bed [14].

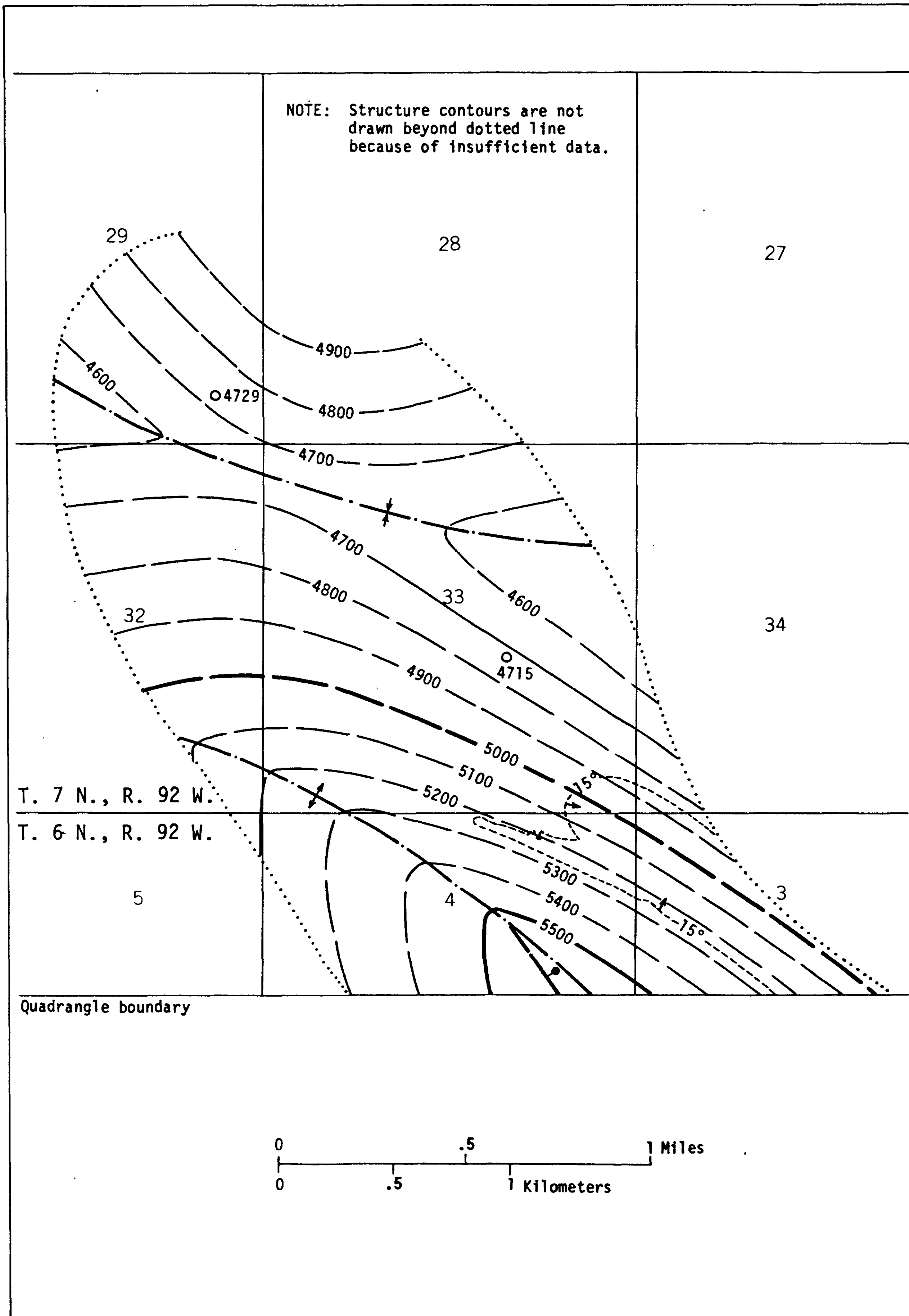


FIGURE 14. — Structure contour map of the Middle Coal Group, coal bed [14].

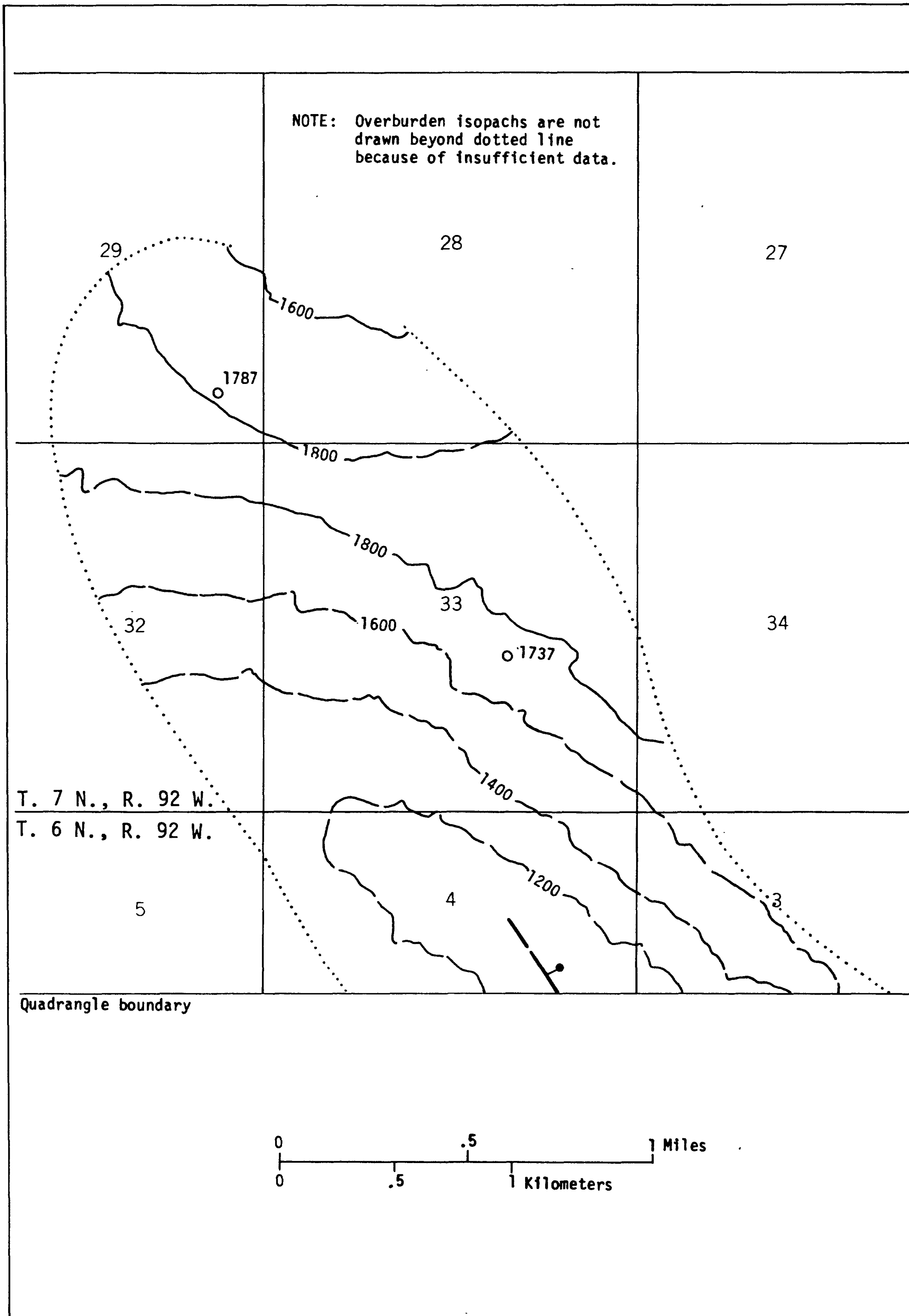


FIGURE 15. — Overburden isopach map of the Middle Coal Group, coal bed [14].

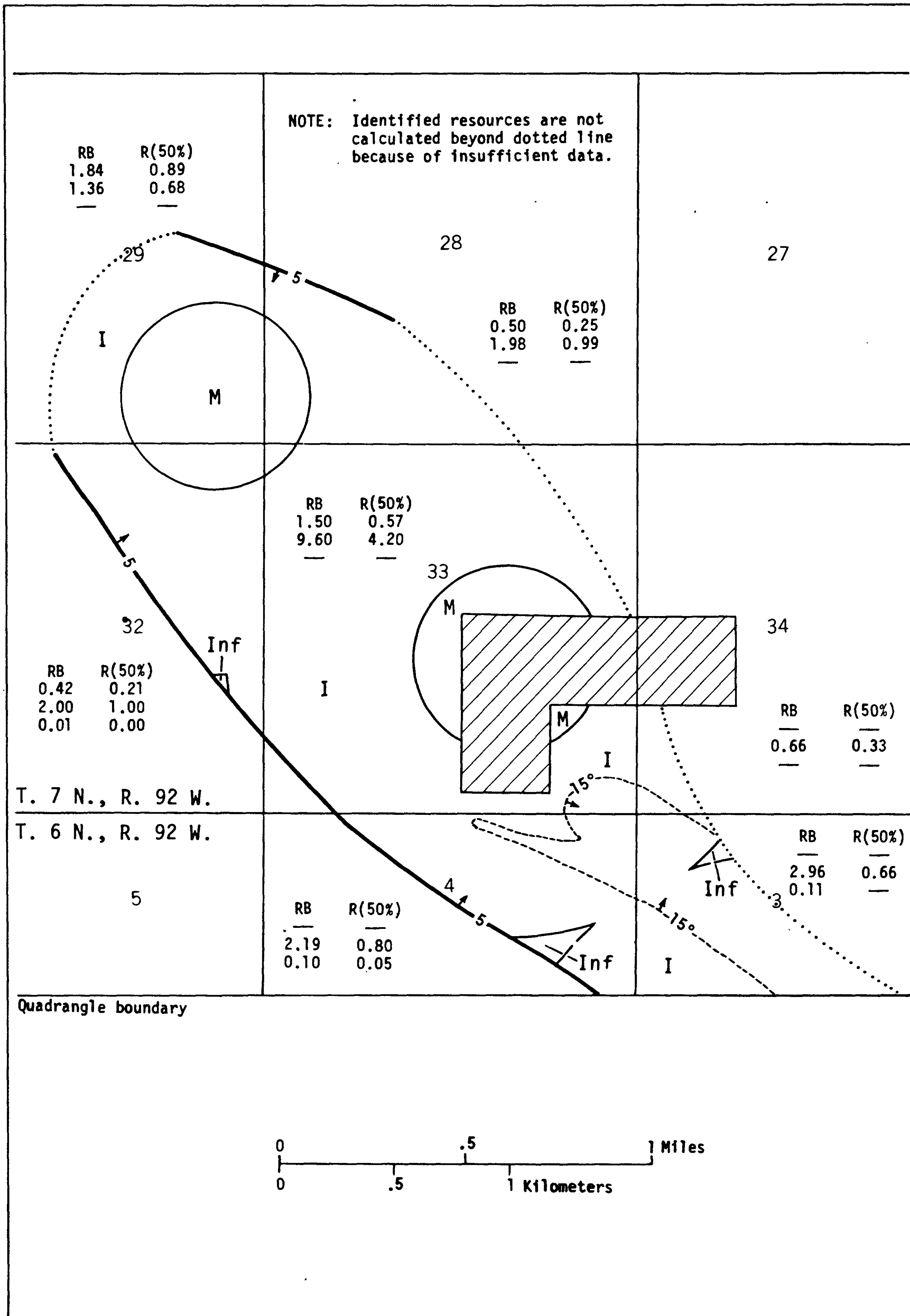


FIGURE 16. — Areal distribution and identified resources map of the Middle Coal Group, coal bed [14].

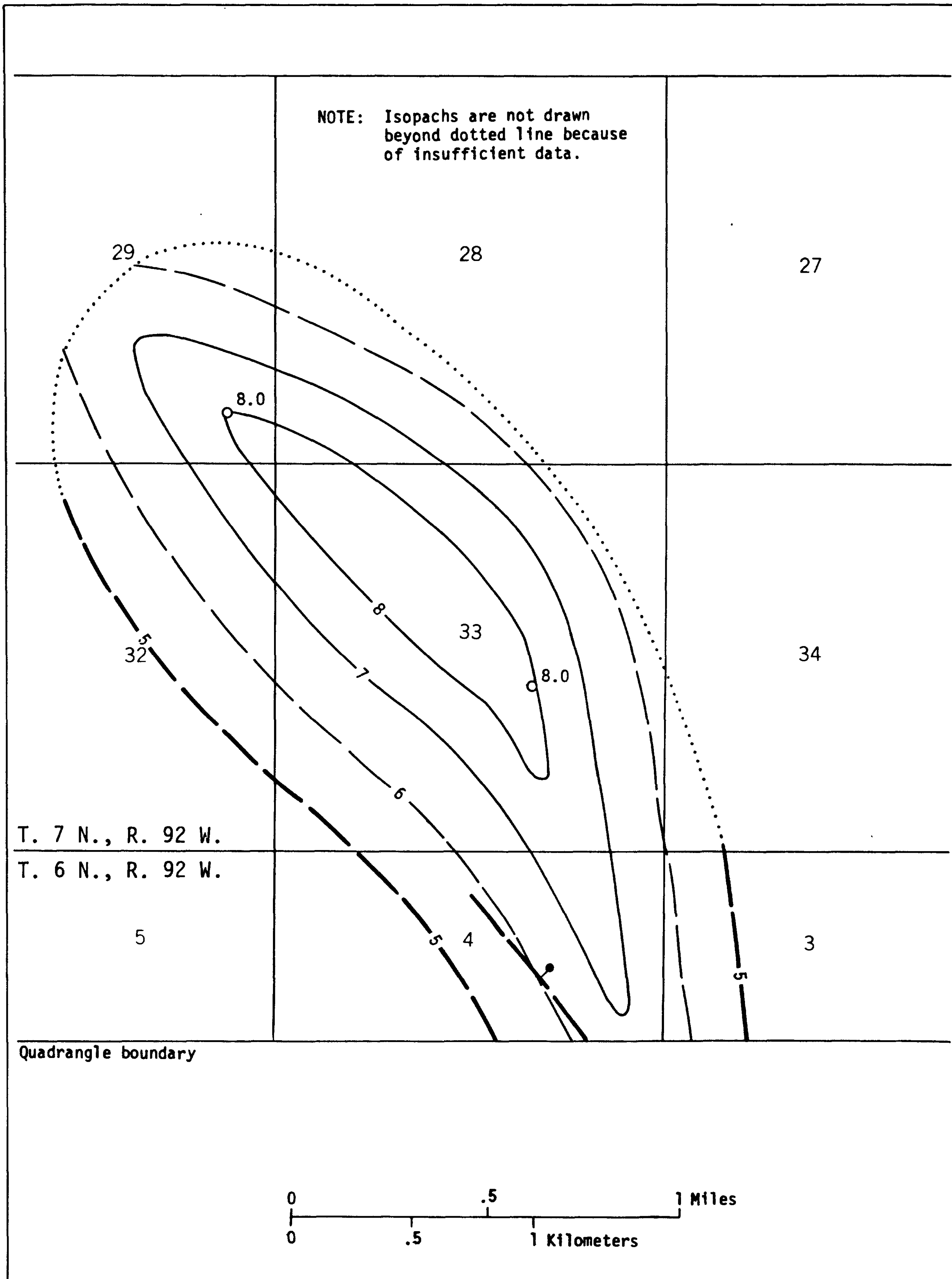


FIGURE 17. — Isopach map of the Middle Coal Group, coal bed [15].

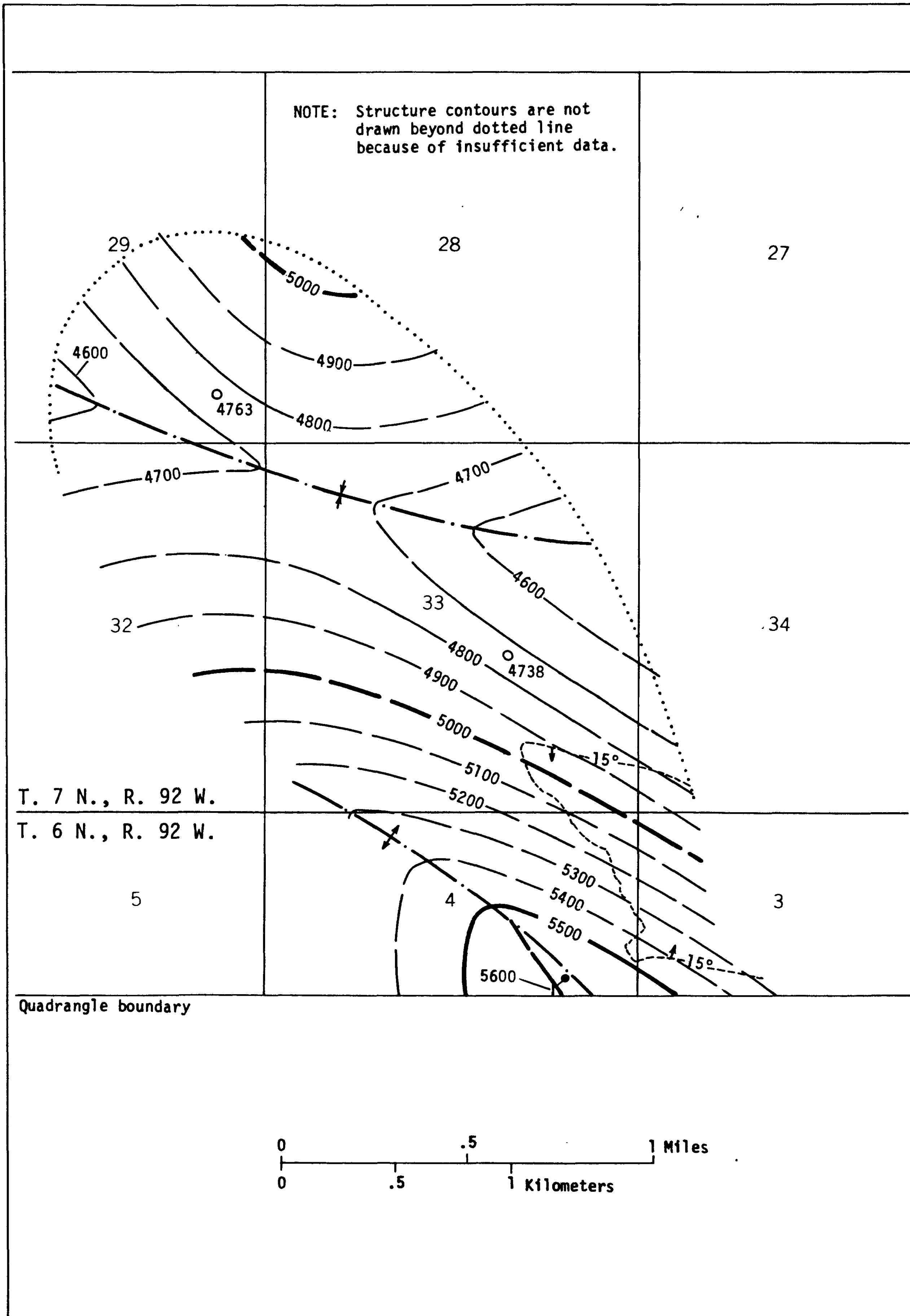


FIGURE 18. — Structure contour map of the Middle Coal Group, coal bed [15].

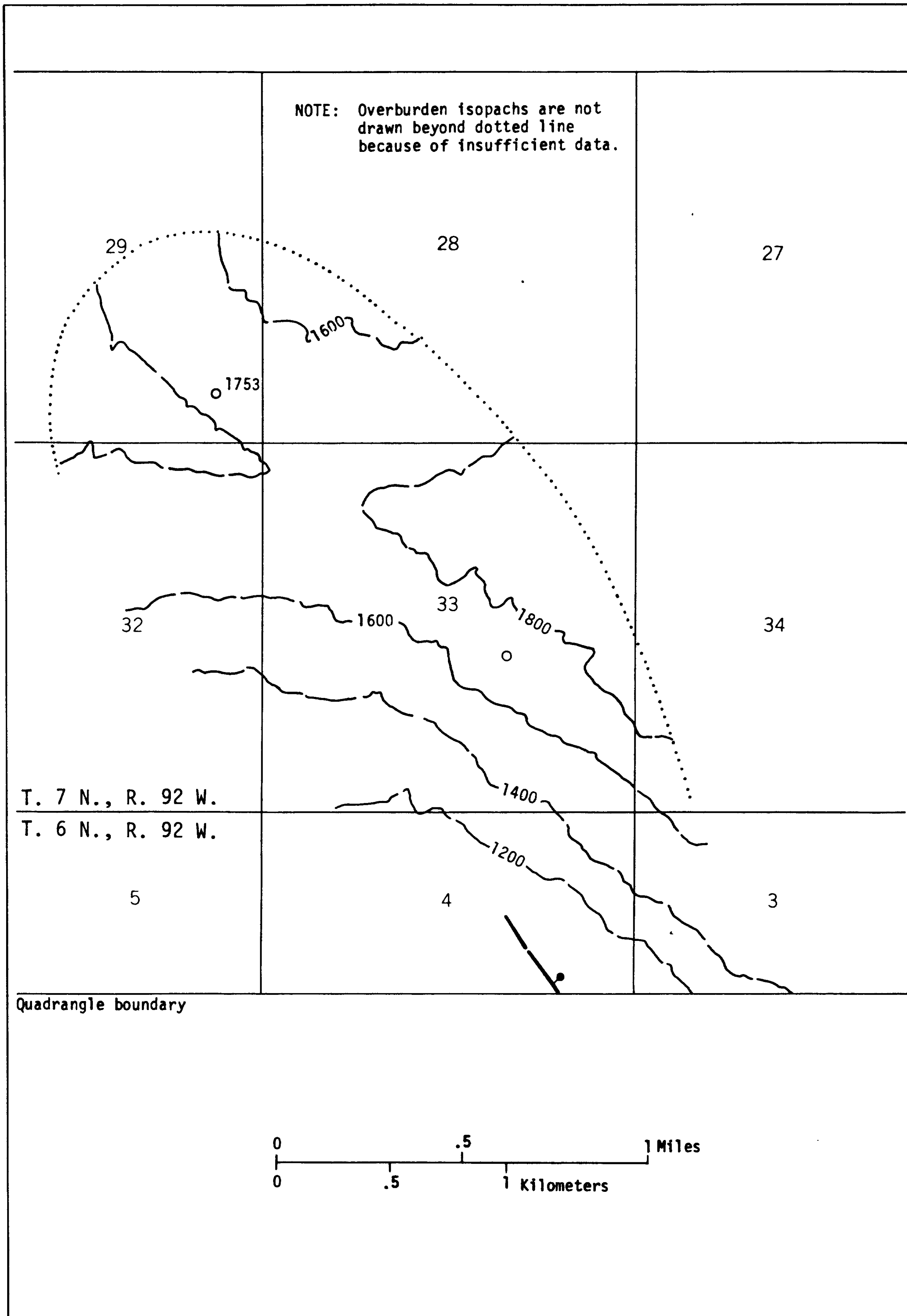


FIGURE 19. — Overburden isopach map of the Middle Coal Group, coal bed [15].

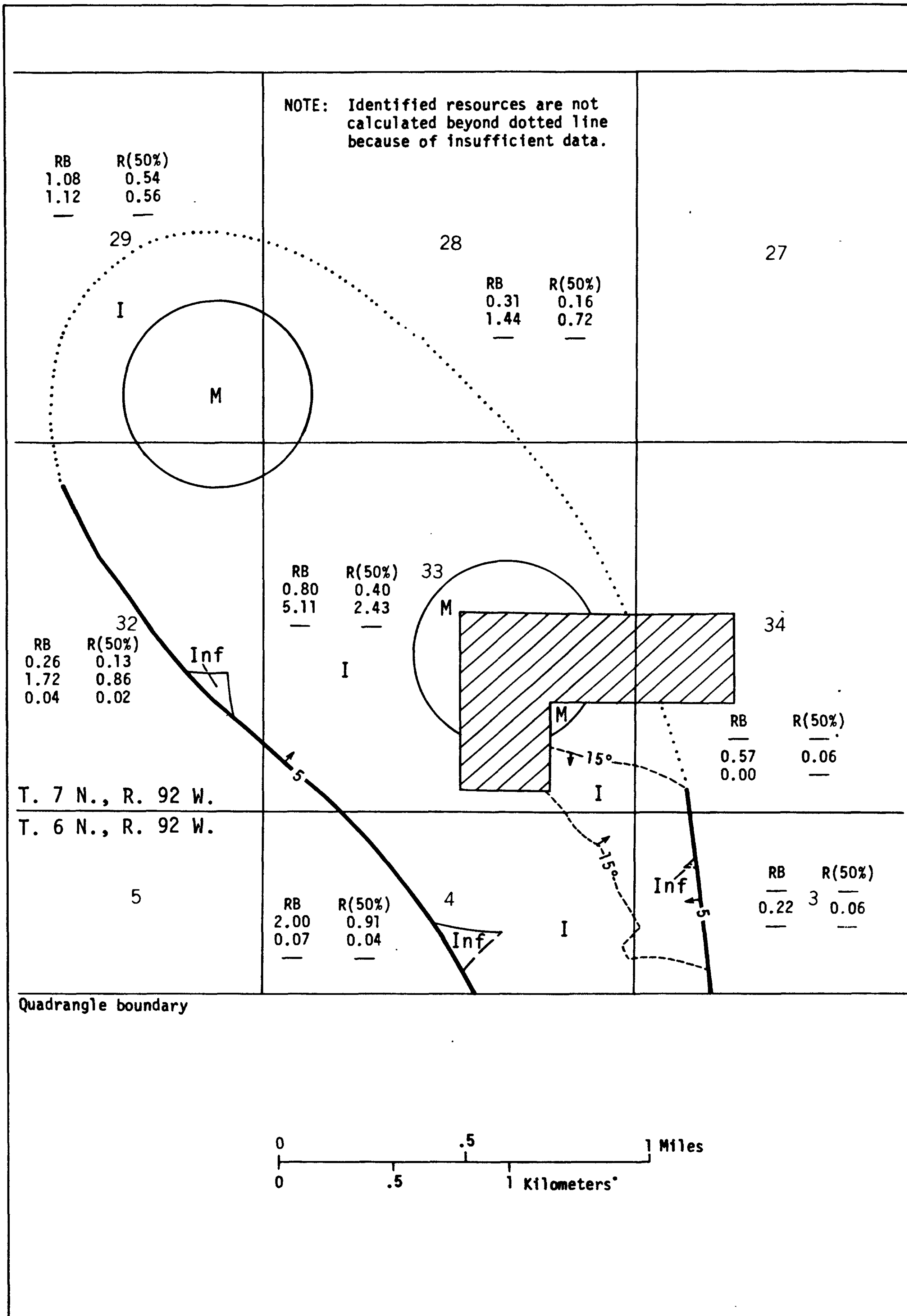


FIGURE 20. — Areal distribution and identified resources map of the Middle Coal Group, coal bed [15].

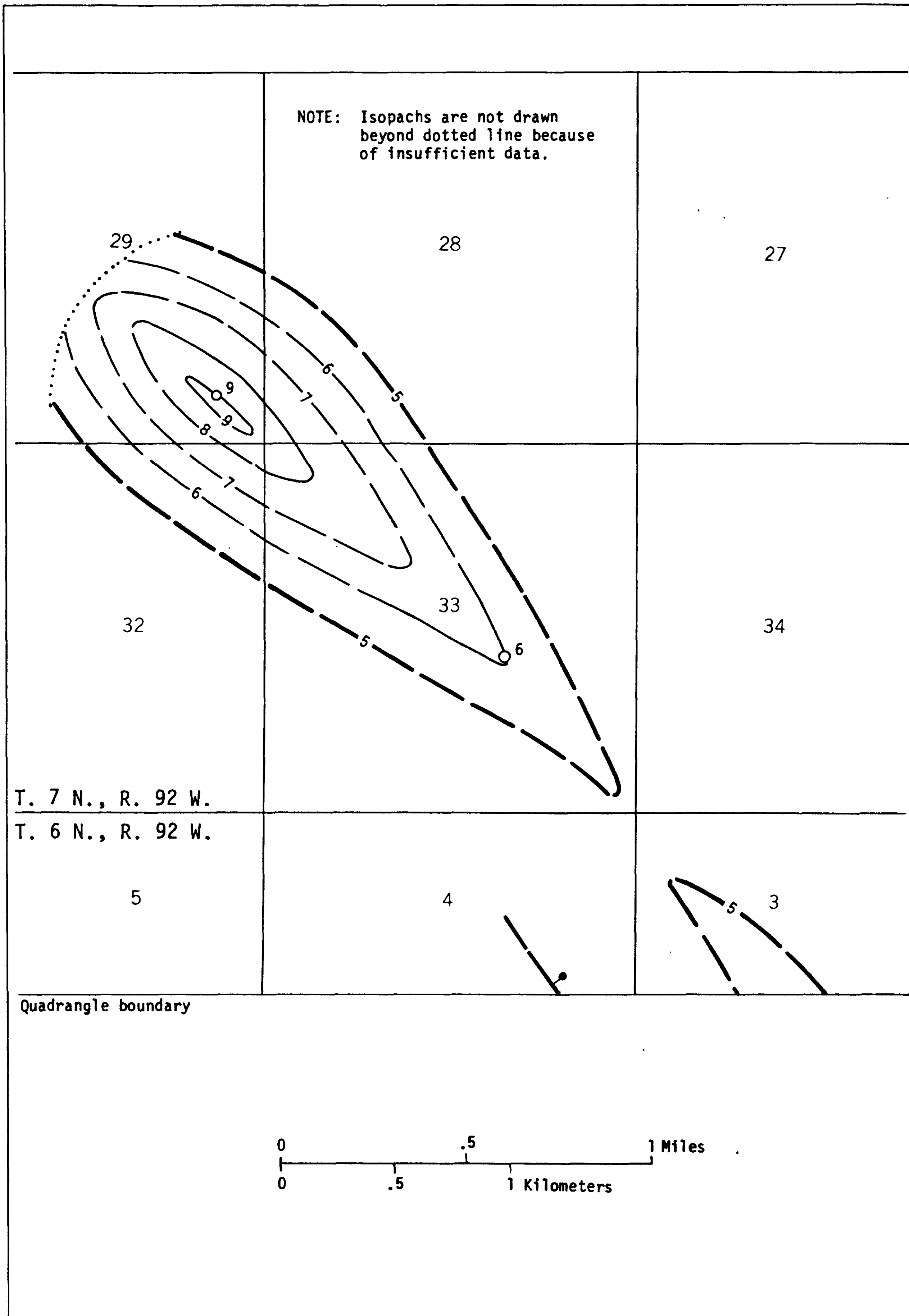


FIGURE 21. — Isopach map of the Upper Coal Group, coal bed [3].

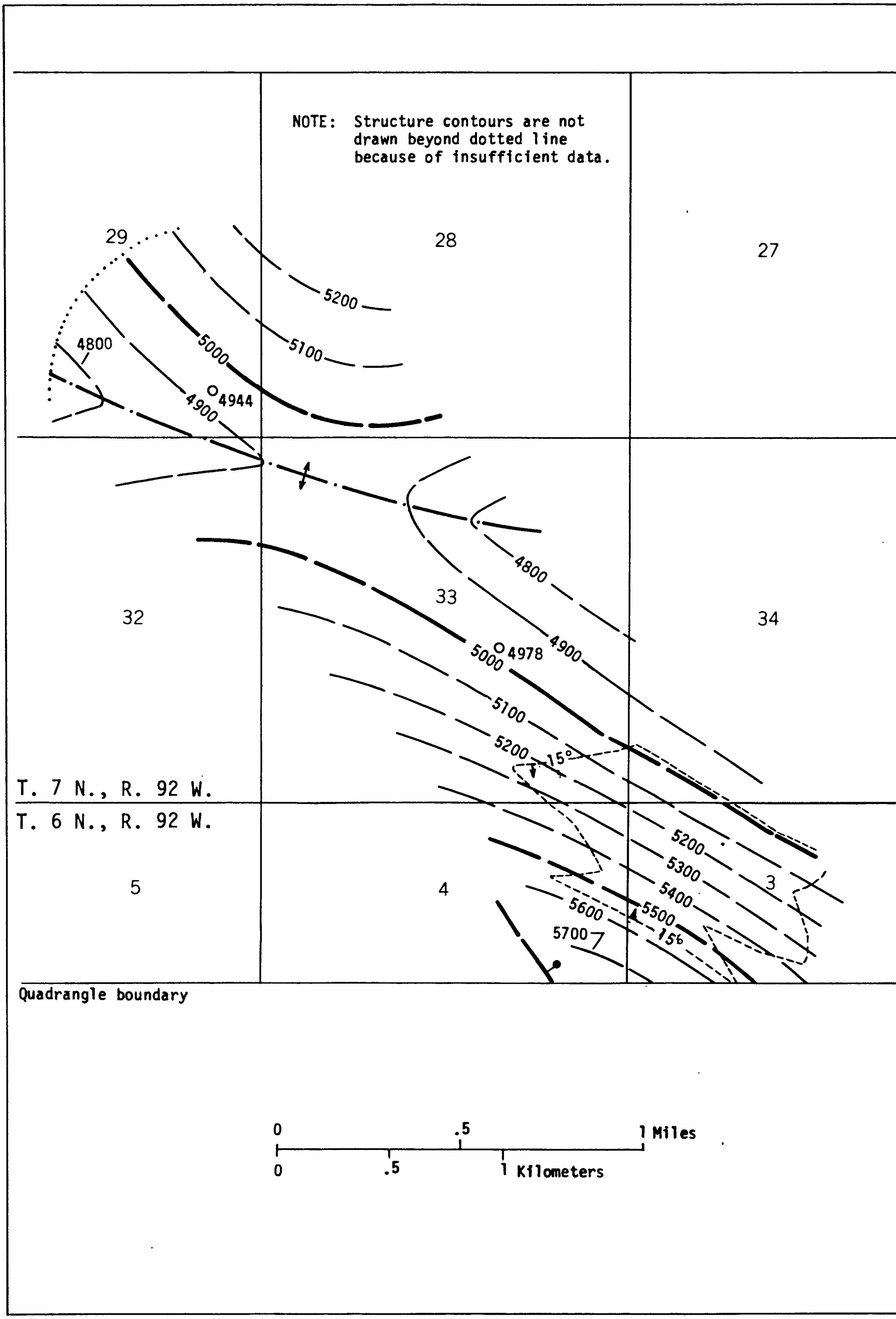


FIGURE 22. — Structure contour map of the Upper Coal Group, coal bed [3].

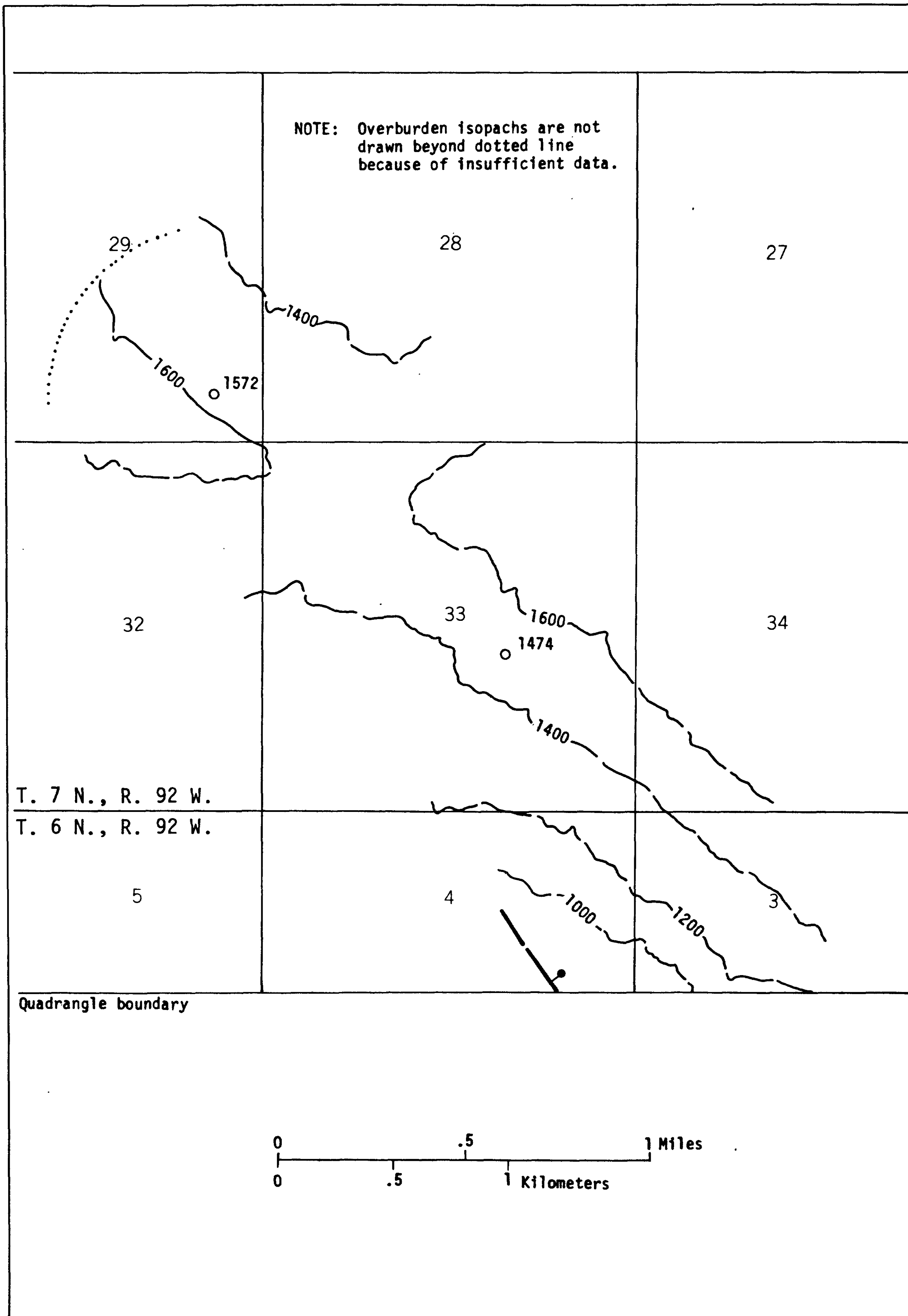


FIGURE 23. — Overburden isopach map of the Upper Coal Group, coal bed [3].

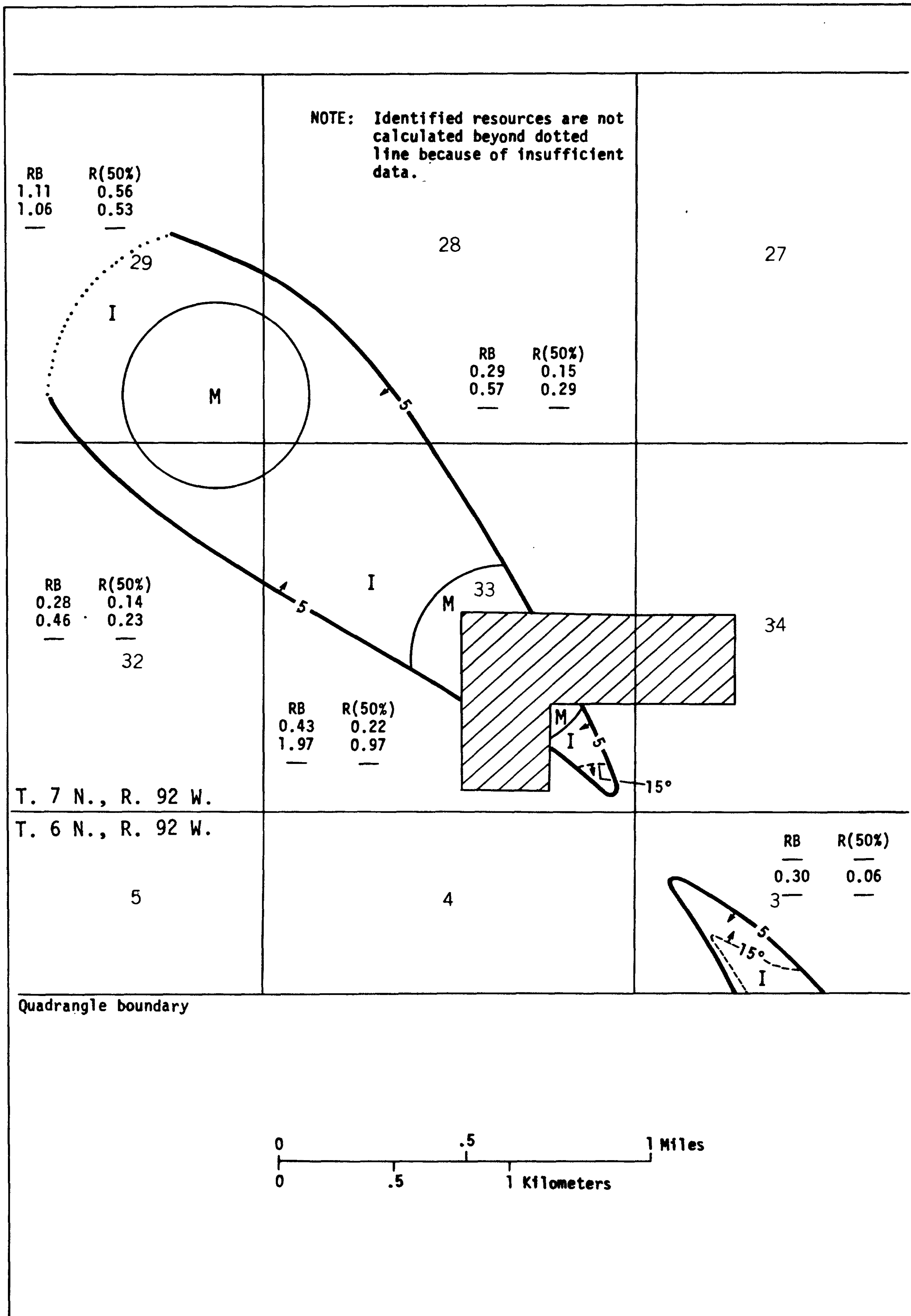


FIGURE 24. — Areal distribution and identified resources map of the Upper Coal Group, coal bed [3].

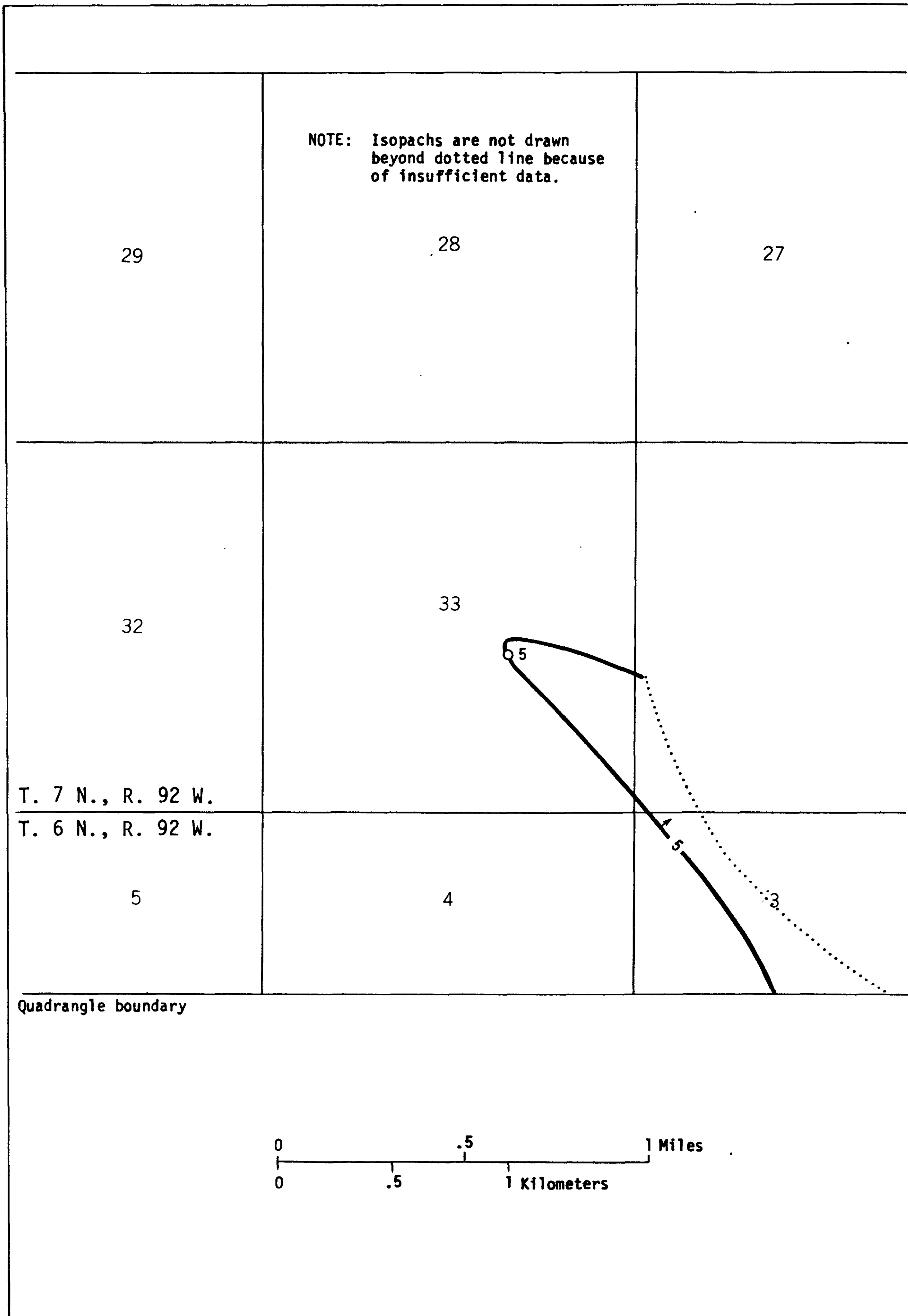


FIGURE 25. — Isopach map of the Upper Coal Group, coal bed [4].

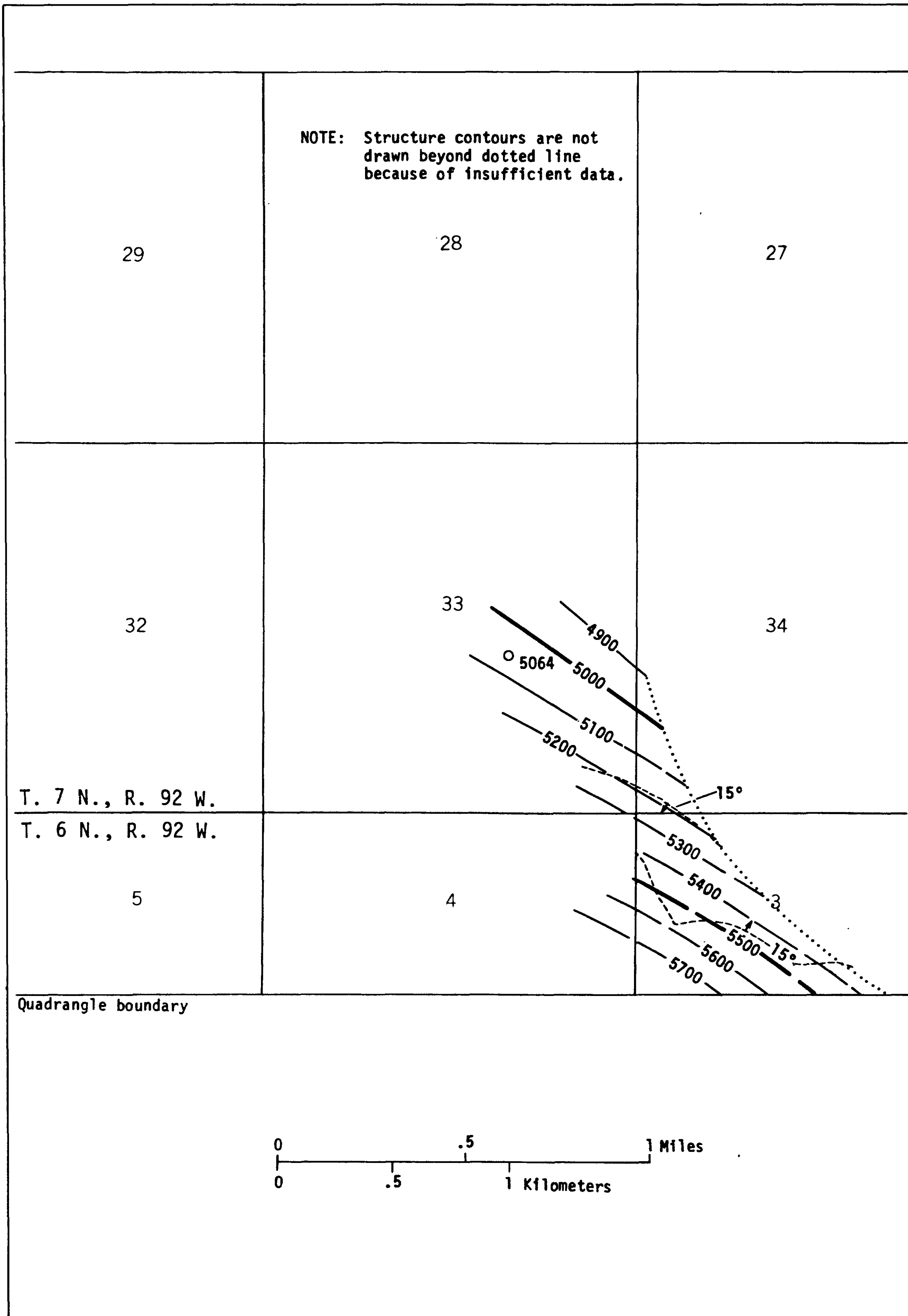


FIGURE 26. — Structure contour map of the Upper Coal Group, coal bed [4].

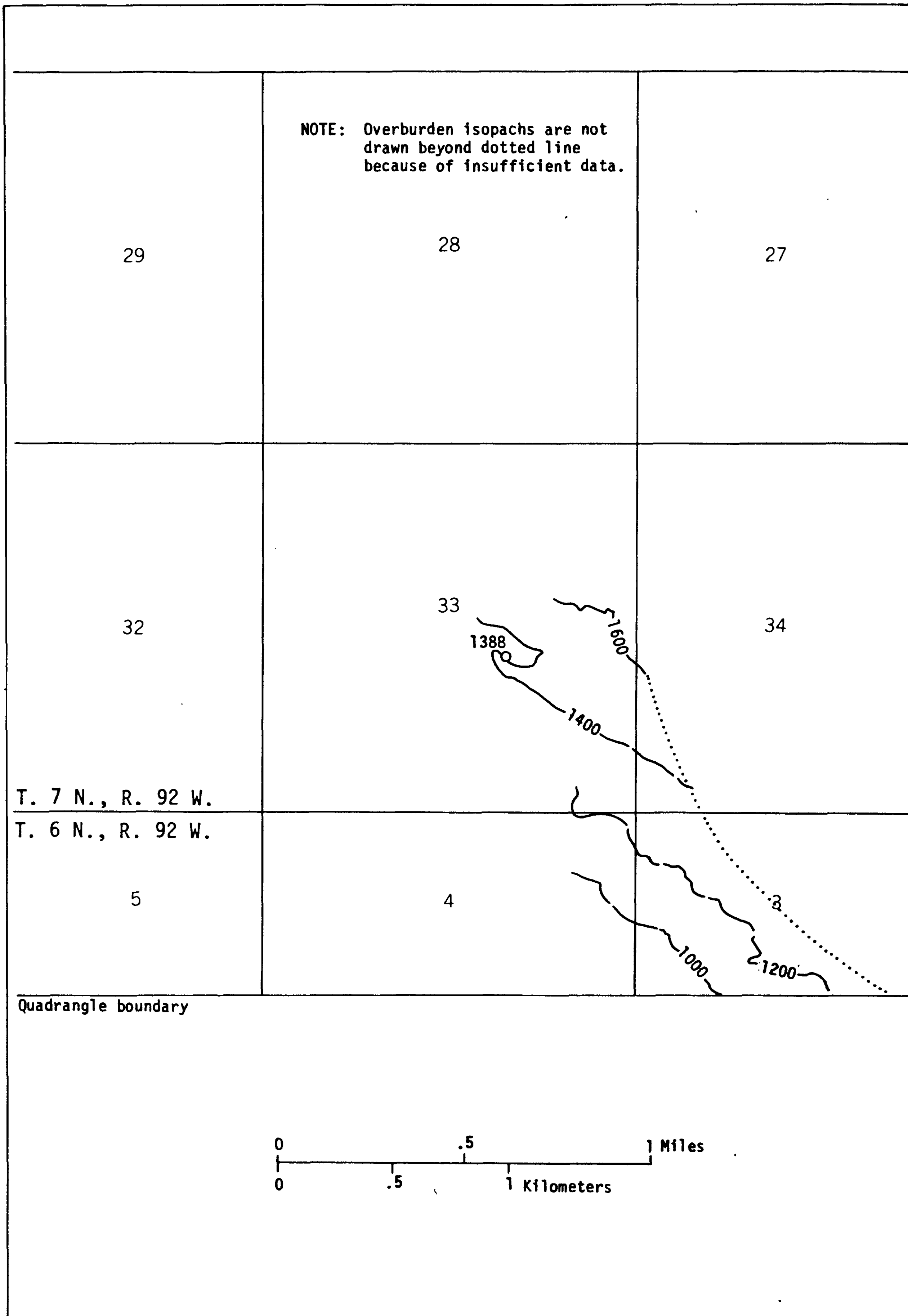


FIGURE 27. — Overburden isopach map of the Upper Coal Group, coal bed [4].

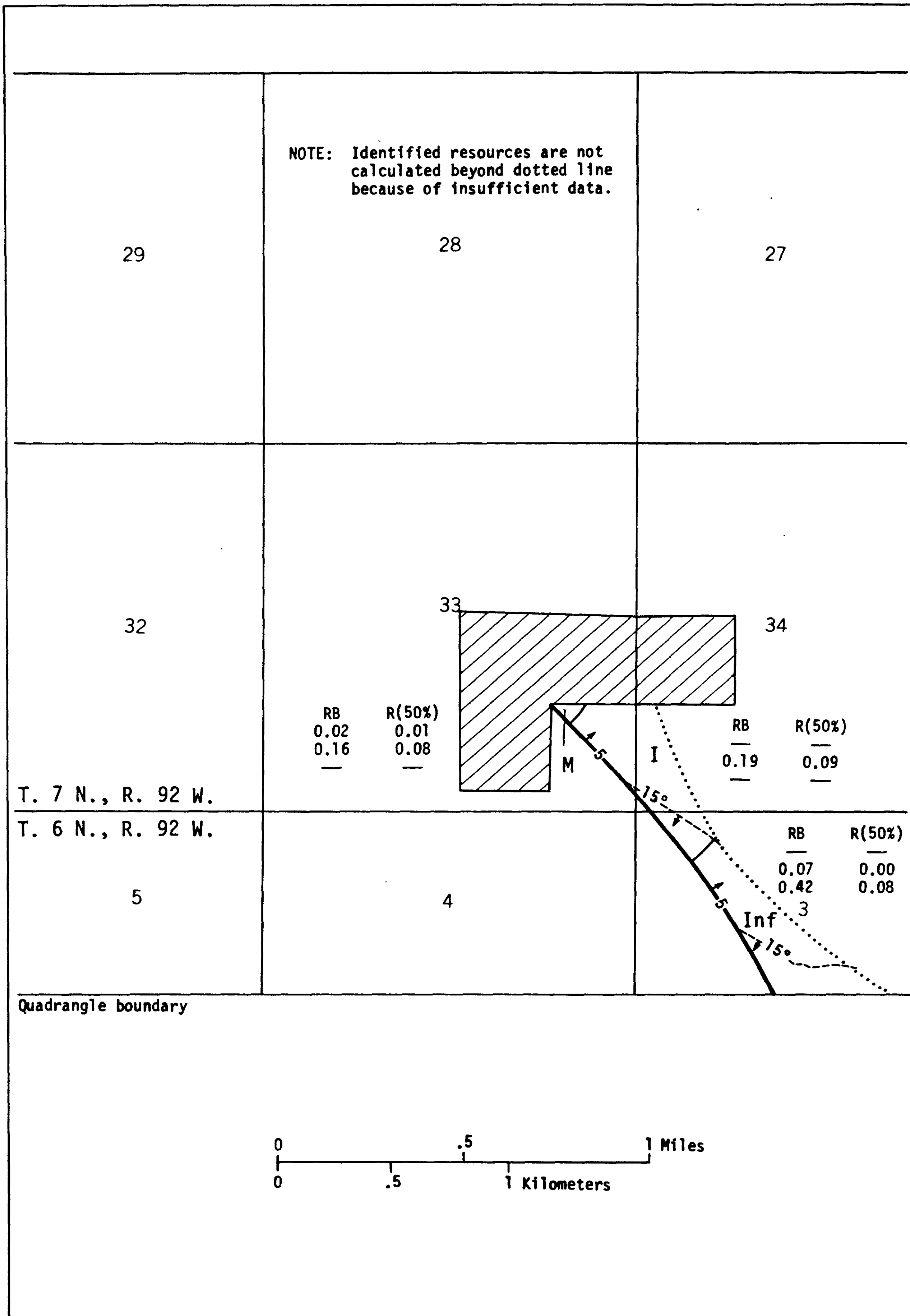


FIGURE 28. — Areal distribution and identified resources map of the Upper Coal Group, coal bed [4].

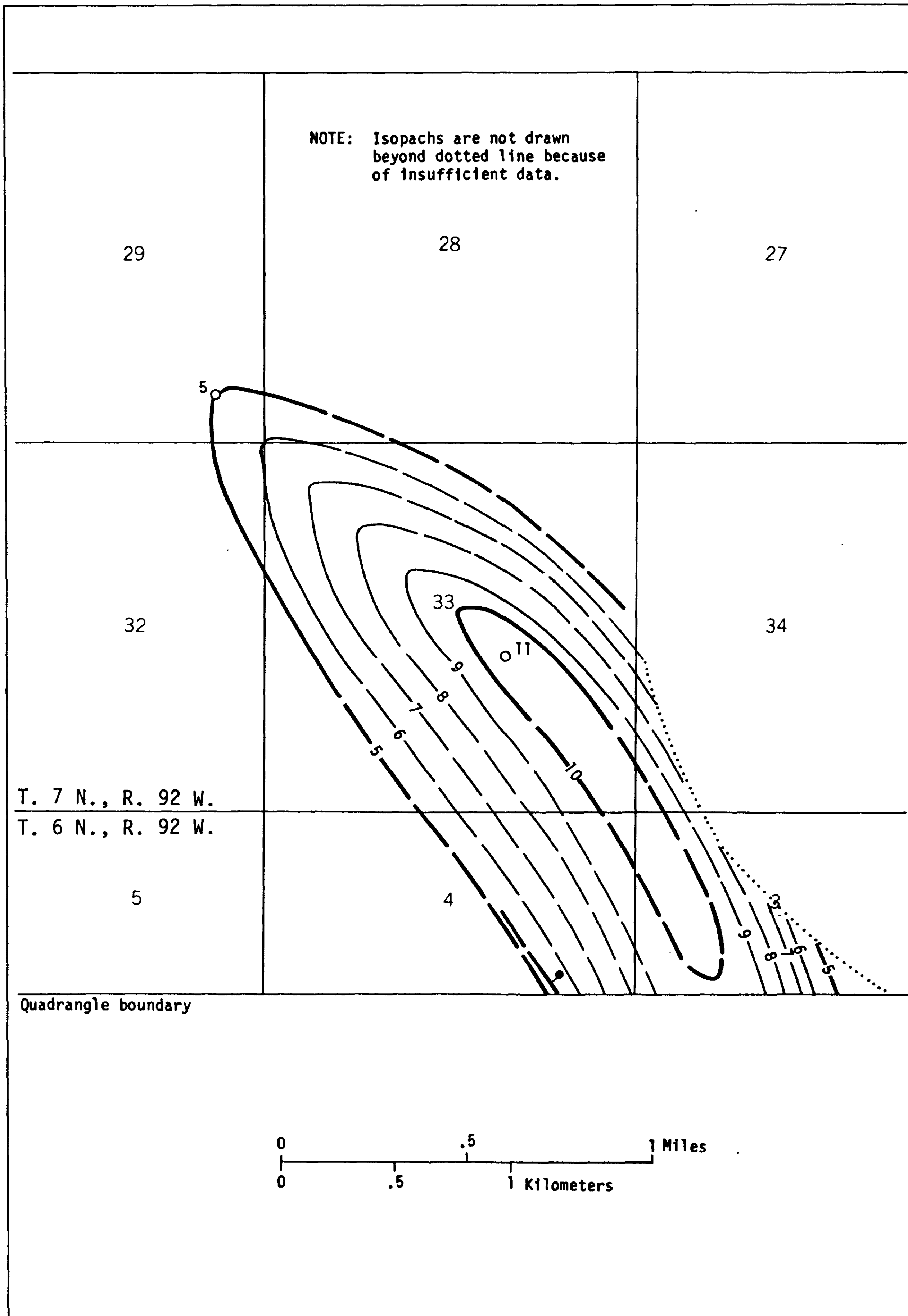


FIGURE 29. — Isopach map of the Upper Coal Group, coal bed [9].

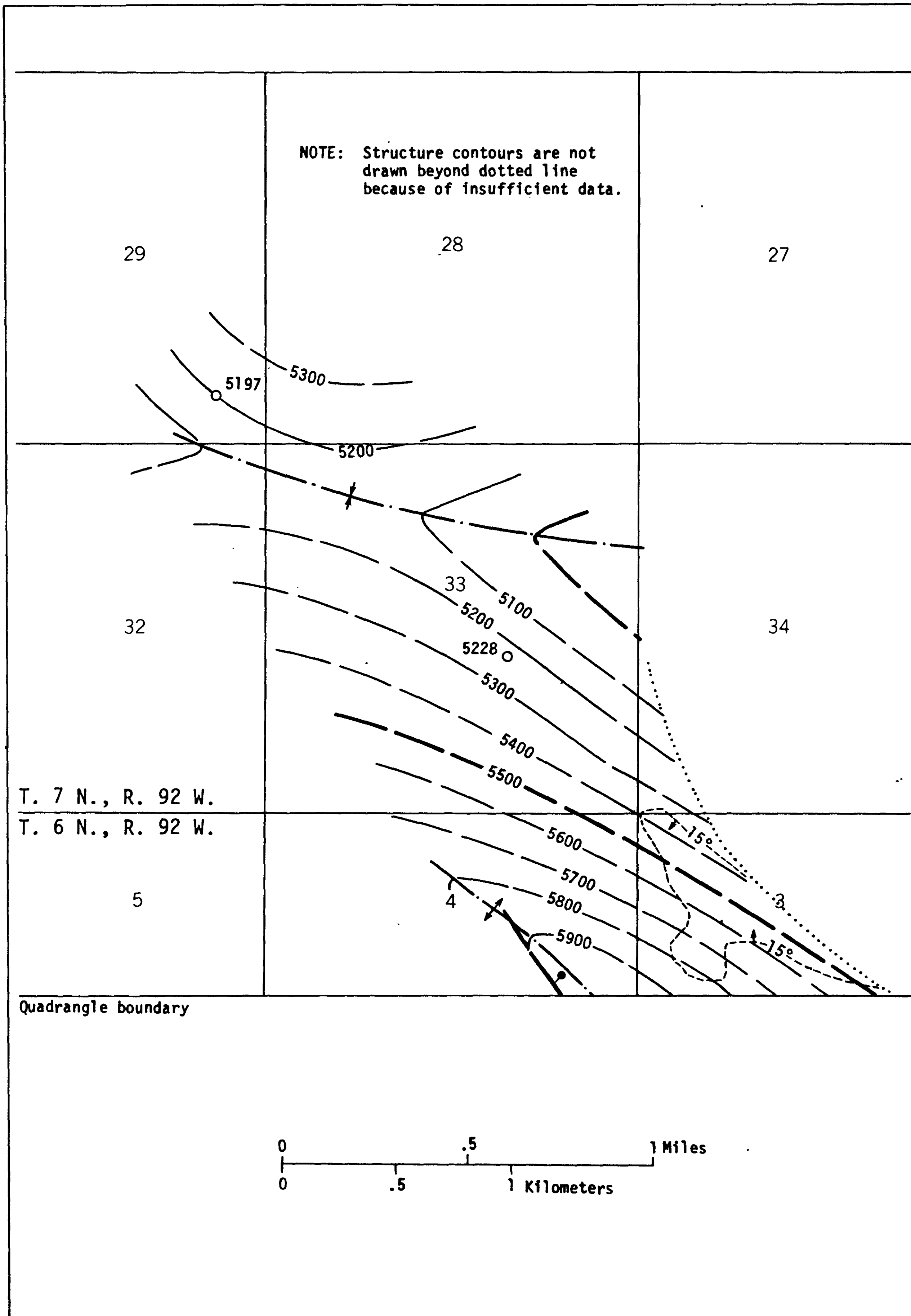


FIGURE 30. — Structure contour map of the Upper Coal Group, coal bed [9].

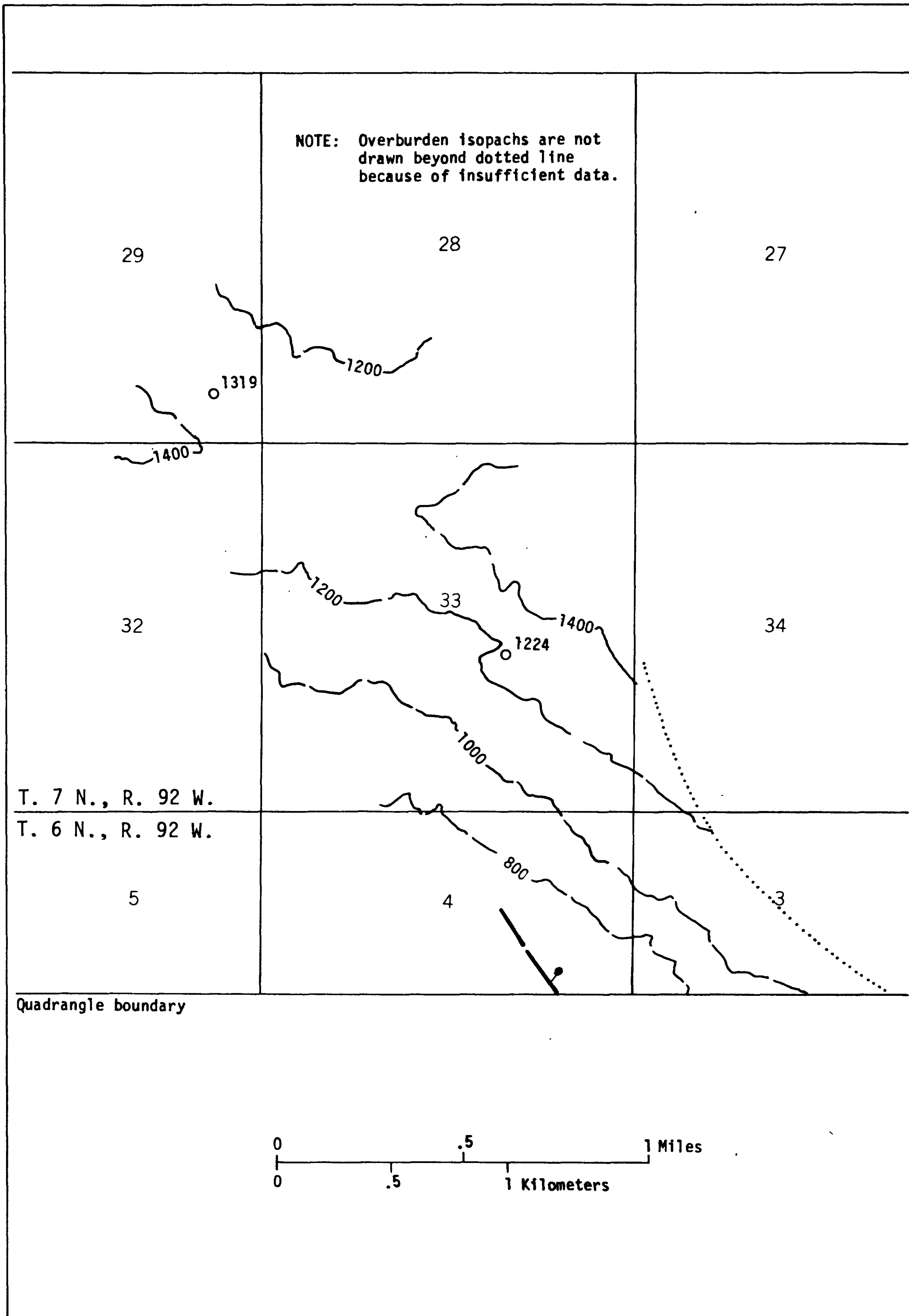


FIGURE 31. — Overburden isopach map of the Upper Coal Group, coal bed [9].

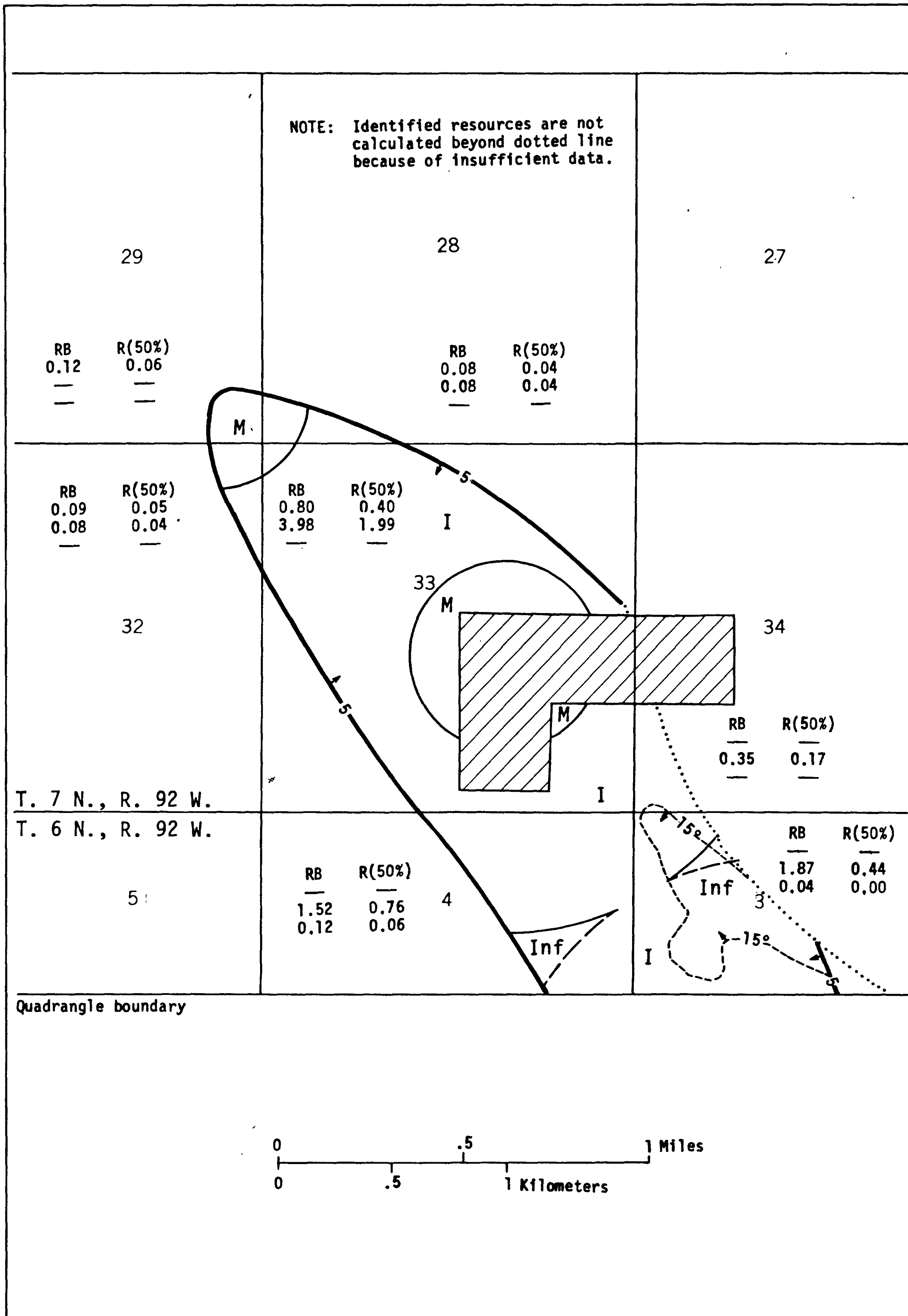


FIGURE 32. — Areal distribution and identified resources map of the Upper Coal Group, coal bed [9].

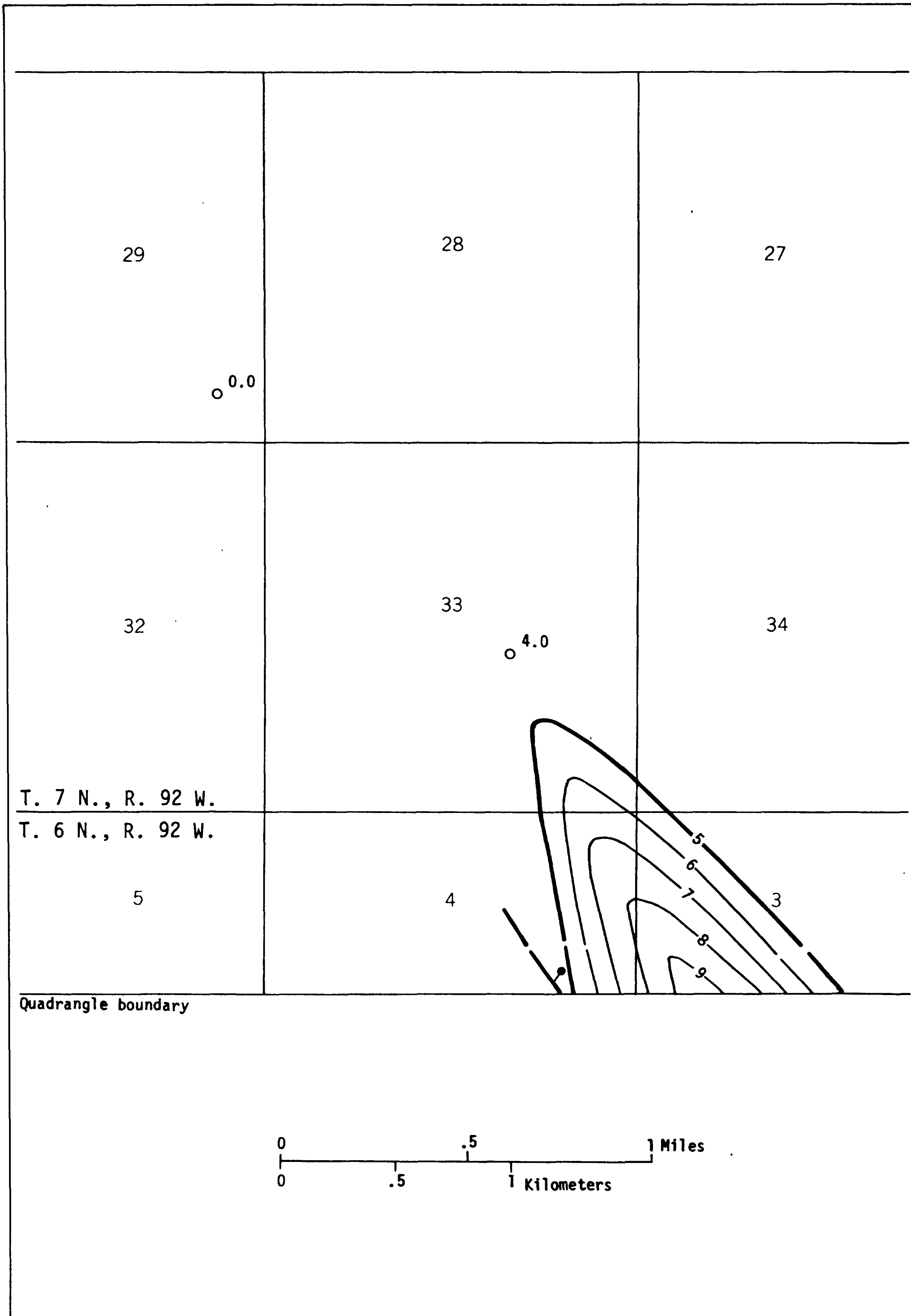


FIGURE 33. — Isopach map of the Upper Coal Group, coal bed [10].

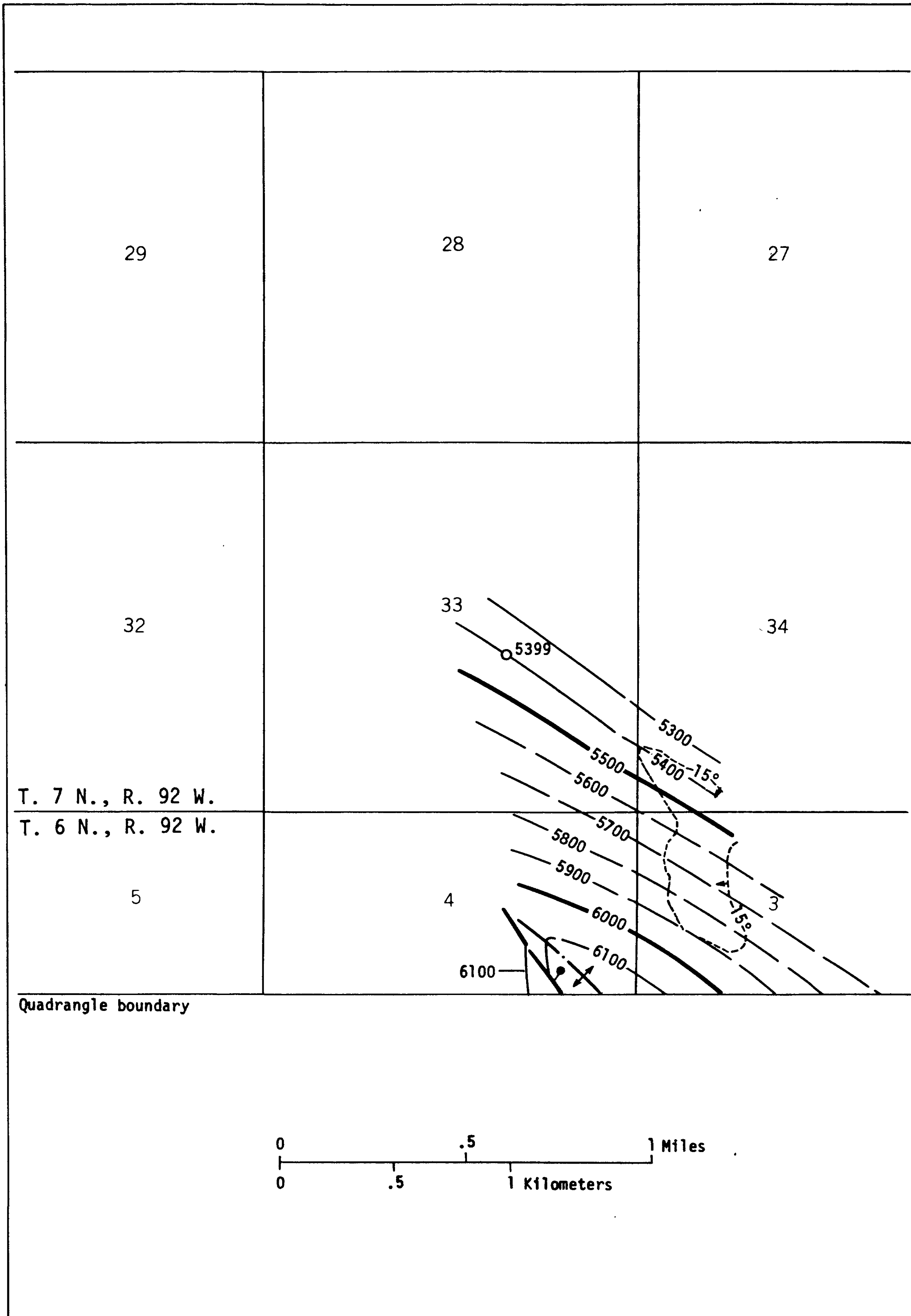


FIGURE 34. — Structure contour map of the Upper Coal Group, coal bed [10].

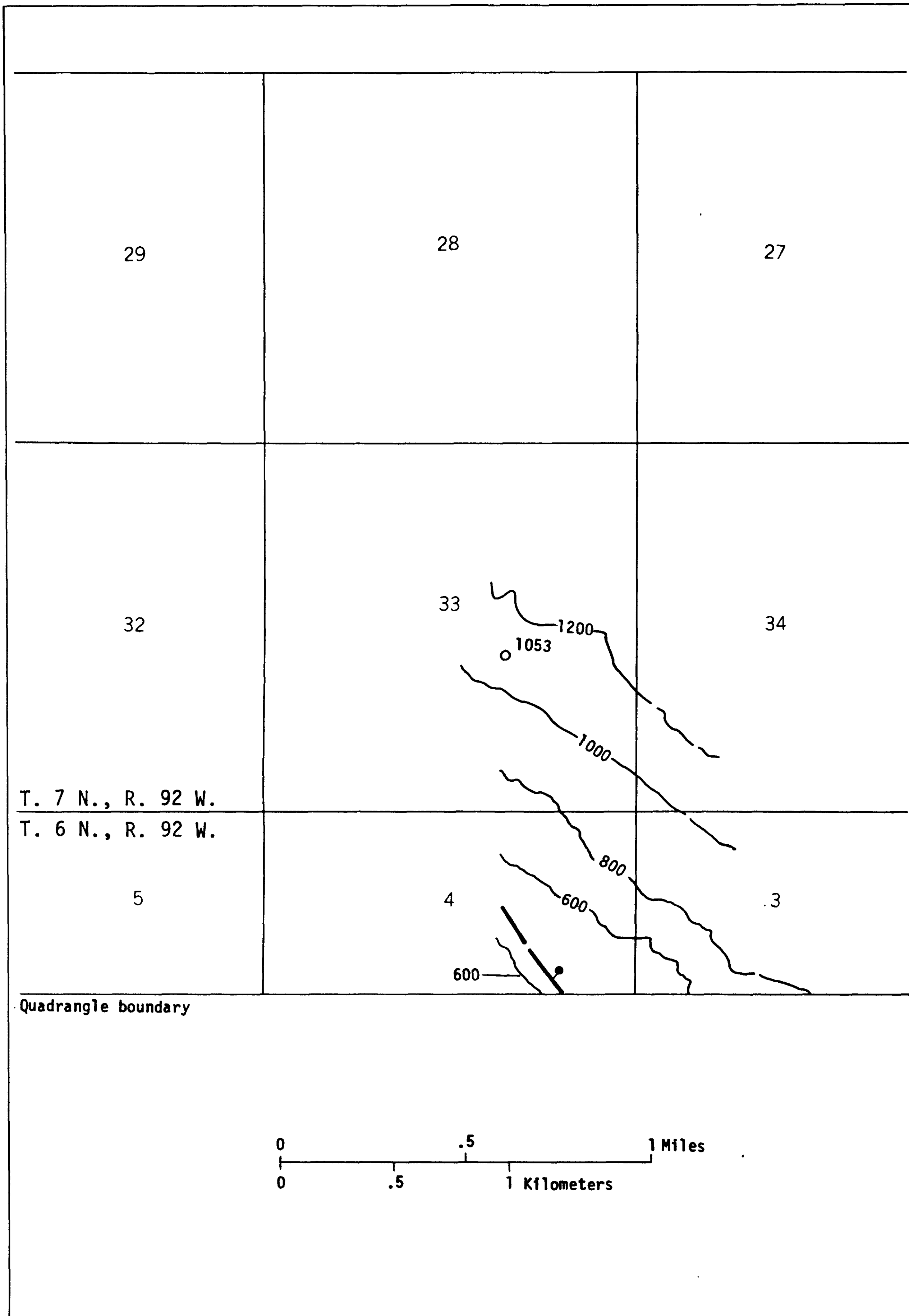


FIGURE 35. — Overburden isopach map of the Upper Coal Group, coal bed [10].

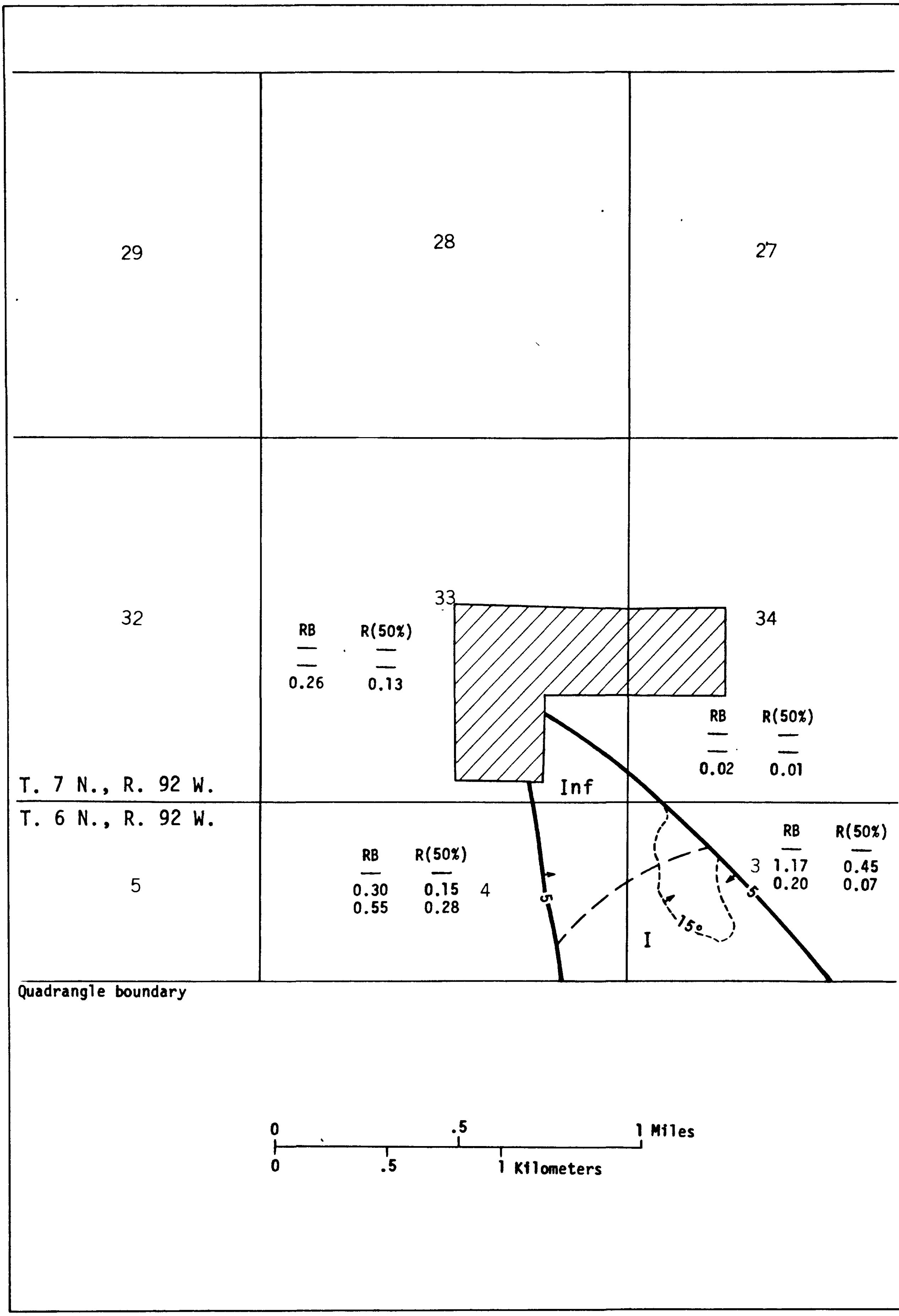


FIGURE 36. — Areal distribution and identified resources map of the Upper Coal Group, coal bed [10].