Cumberland-Marlboro ‘basin’ basement drilling results – 2015: Cumberland, Hoke and Scotland counties, North Carolina

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Cumberland-Marlboro 'basin' basement drilling results – 2015: Cumberland, Hoke and Scotland counties, North Carolina

Abstract

State-funded continuous Rotasonic coring in the Cumberland-Marlboro basin (CMB) was undertaken to evaluate the existence of a possible Triassic rift / lacustrine 'basin' beneath the Atlantic Coastal Plain for on-shore hydrocarbon potential.

The CMB is represented by a large negative aeromagnetic anomaly buried beneath thin (200-400-feet-thick) Coastal Plain sedimentary cover. The anomaly is strike parallel and seaward of the Triassic Deep River rift basin previously assessed by the U.S. Geological Survey (USGS) for hydrocarbon potential. Several documents in the geologic literature suggest that a Triassic rift / lacustrine basin may be present coincident with this magnetic anomaly. The state groundwater well database (GW-1) provided equivocal data suggesting the potential presence of Triassic strata and limited information on bedrock well completions. Two basement studies present equivocal data that could be interpreted either as paleo-weathering of metavolcanic or metasedimentary rocks or deeply weathered paleo-saprolite developed on Triassic strata.

Three Rotasonic drill holes were advanced continuously from the surface into basement and recovered fresh-, four-inch diameter cores of basement rock along the CMB anomaly's strike extent at three locations, one each in Cumberland, Hoke and Scotland counties, North Carolina. All three basement cores encountered rock described in the field as metavolcanic rock and/or metasedimentary rock. Petrographic study of thin sections indicates the basement rocks are of metasedimentary origin. Thus a large Triassic rift / lacustrine basin is not the cause of the negative aeromagnetic anomaly that occurs along strike where the holes were drilled. However, the presence of a smaller rift / lacustrine basin like that found in Bertie County, or Camden County, North Carolina, cannot be precluded, and the CMB may yet exist though significantly reduced size to that area in South Carolina suggested by water well data.

Contents

Page

Figures

Page

Table

Introduction

This report summarizes the North Carolina Geological Survey's 2015 basement drilling investigations of the unassessed Cumberland-Marlboro 'basin' (basin #1250701161 of the USGS's national basin inventory – see also **Milici *et al.*, 2012**). The drilling objective was to determine the rock type corresponding to a large negative aeromagnetic anomaly that is strike parallel and seaward of the Deep River Triassic rift / lacustrine basin lying beneath a thin cover of unconsolidated Coastal Plain sediments. Rotasonic coring through the thin (200-400 feet) overburden of the unconsolidated Coastal Plain sediments recovered fresh 4-inch diameter Rotasonic cores of basement rock (**Fig. 1**). Drilling was confined to 'state owned' land by direction of the North Carolina General Assembly in their FY2014-15 appropriation. Budget limitations controlled the number of holes that were drilled.

USGS Investigation into the Cumberland-Marlboro 'basin' of eastern North Carolina

As part of its ongoing assessment of the undiscovered, technically recoverable oil and natural gas resources of the United States, in 2011 the U.S. Geological Survey (USGS) examined a number of Mesozoic rift basins within the states bordering the Atlantic Ocean. This assessment concluded that a mean of 3.86 trillion cubic feet of gas and 135 million barrels of natural gas liquids remain to be found in five of these rift basins (**Milici *et al.*, 2012**). These basins are the Taylorsville basin of Virginia and Maryland, the Richmond basin of Virginia, the southern half of the Newark basin of New Jersey and Pennsylvania, the Deep River basin of North Carolina, and the Dan River-Danville basin of North Carolina and Virginia. These basins were assessed because there were sufficient data in the form of stratigraphic and petroleum systems indications from drilled wells, outcrop sample analyses, and supporting geophysical data (reflection seismic profiles and aeromagnetic anomaly maps). **Coleman (2009)** provided an overview of the history of oil and gas exploration and petroleum geology of North Carolina State Waters and the on-going USGS assessment of East Coast Mesozoic basins.

Other basins were identified and examined, but not assessed because of the lack of sufficient data to confirm the potential presence of a petroleum system and possible petroleum accumulations. Those basins examined, but not assessed are the Hartford basin, the north half of the Newark basin, the Gettysburg basin, the Culpeper basin, several basins combined as the Delmarva basins, the Cumberland-Marlboro 'basin', the Florence basin, the South Georgia basin and the North Florida basin. Detailed geologic information on all of these and other identified onshore Atlantic coastal states Mesozoic rift basins was presented in **Coleman *et al.* (2015).** This discussion of the Cumberland-Marlboro 'basin' is extracted from **Coleman *et al.* (2015)** and older literature that originally proposed the existence of the basin.

Several small Triassic basins occur beneath the North Carolina Coastal Plain. These include the Bertie County basin (**Weems *et al.*, 2007**), where clearly lacustrine strata have not been found. **Richards (1954a, 1954b)** noted an apparent Triassic basin with a small show of gas in the duGrandlee Exploration Co. well (with a total depth of 6,421 feet) from Camden County. In this instance, carbonaceous, probably lacustrine shale was identified in drill cuttings from the Camden County well (**Richards, 1954b**).

The Cumberland-Marlboro 'basin' was identified from anomalously low aeromagnetic data and the presence of two water wells in Marlboro County, South Carolina (**Benson, 1992**). Benson identified these two water wells as penetrating the Mesozoic rift strata, and these wells lay within the area of anomalously low aeromagnetic character (**Fig. 2**; **U. S. Geological Survey and National Geophysical Data Center, 2002).** No oil and gas wells had been drilled within the Cumberland-Marlboro 'basin' outline, and no reflection seismic profiles were known to exist to confirm its presence.

This 'basin' had been previously interpreted by **Bonini and Woollard (1960)** and **Bonini (1964)** as a "buried Triassic [b]asin" and given the name "Fayetteville basin". Its identification was based on a lower than expected basement velocity of 12,500 feet/second from refraction seismic data and interpretation that two wells with bottom cuttings in sericitic phyllite and volcanic material were, in fact, "Triassic sediments (?)". **Schipf (1964)** disagreed with **Bonini (1964)** citing his groundwater study data **(Schipf, 1961)** as evidence that the 'basin' was a geophysical anomaly (velocity and magnetic low) associated with metavolcanic-epiclastic rocks of the Eastern Slate Belt **(Brown *et al.*, 1985). Schipf (1964)** cited records from 25 wells in the Fayetteville area which reached total depth in "slate", both according to drillers' and Schipf's logs. **Schipf (1964),** however, recognized the possibility that the gray slates in these wells might be gray shales of Triassic age, such as those of the Cumnock Formation in the Deep River basin, but considered it "unlikely".

Examination of the water well data from Marlboro County, South Carolina, revealed that one well log (MLB-0183, **Figs. 3, 4**) showed the possible presence of Mesozoic synrift sedimentary rock beneath Cretaceous strata of the Atlantic Coastal Plain. The possible presence of Mesozoic synrift strata in the two wells illustrated by **Benson (1992)** could not be confirmed from online South Carolina well data (https://www.dnr.sc.gov/hydro/gl_home.html). **Benson (1992)** had previously described these wells as penetrating "unmetamorphosed presumed lower Mesozoic (Upper Triassic-Lower Jurassic) synrift sedimentary rock sand[stone] or diabase". He did not illustrate any water wells from North Carolina with these characteristics within the Cumberland-Marlboro 'basin' outline.

Examination of the few North Carolina water wells within the area of the Cumberland-Marlboro 'basin' encountered rocks potentially reflective of Mesozoic syn-rift sedimentary rocks (i.e., HO-P-1-70, "chips of quartz-sericite phyllite...[with] some chips of fine-grained quartzite"; CD-P-1-67, "chips of metagraywacke with a poor slaty cleavage..., relict sedimentary..., 80 percent of rock is ... quartz sand and silt grains"; CD-T-1-86, "sericite phyllite and metasandstone chips consisting of quartz…, angular sericite…, and minor carbonate"; and SA-T-1-XX, "chips of slaty metamudstone…[r]ock has no chlorite, is very fine grained, and is only very slightly metamorphosed"; **Lawrence and Hoffman, 1993**). For well locations see **Lawrence and Hoffman (1993)**. Other than the phrase "poor slaty cleavage" and the mention of "apparent" metamorphic magnetite, very minor chlorite, and white mica making up about 20% of one of the samples (CD-P-1-67), there were no other rock data available at the time to clearly indicate metamorphic terrain as indicated by the other adjacent and surrounding wells (**Lawrence and Hoffman, 1993**). These lithologies did not clearly condemn the potential presence of buried Mesozoic rift basins; however, they do support the presence of a low aeromagnetic anomaly.

The North Carolina Geological Survey (NCGS) well database (**Nickerson and Hoffman, 1988**) indicates other wells within the 'basin' outline that might have encountered basement lithologies: CD-T-03-68 encountered metasiltstone as basement and SA-T-1-75, CD-P-1-78, CD-P-2-74, CD-T-2-78, apparently reached basement based on geophysical logs, with no published reports of lithology (**Fig. 5**).

Because of the size, shape, geophysical interpretations, and the lack of clear petrographic evidence, further investigations that would clarify the character of the Cumberland-Marlboro 'basin' (CMB) were suggested. These investigations were recommended to include slim-hole coring using standard mining and water well drilling equipment.

The State's groundwater database (GW-1) located in the North Carolina Department of Environmental Quality, Division of Water Resources was also queried for domestic water wells in the footprint of the CMB (**Fig. 2**). North Carolina's water well construction rules (15A NCAC 02C) require drillers to complete a "Form GW-1, Well Construction Record" and submit it to the North Carolina Division of Water Resources (DWR). Each form captures information on intended well use, total depth, casing, and lithology as described by the driller. After receiving a GW-1 form, DWR personnel enter respective data into their GW-1 database, which has been made available to the NC Geological Survey for this study.

The GW-1 database was used to compile water well construction data from the area outlined on the map as the Cumberland-Marlboro 'basin' (CMB). The records were matched first *via* the postal codes within the counties and then reprocessed to include only those data points within the outline of the CMB itself. The three project rock core locations were plotted based on the coordinates in **Table 1**.

A total of 374 groundwater wells were identified within the CMB from either the given latitude and longitude or on the computed latitude and longitude based on the given street address found on the GW-1 form. These wells range in total depth from eight (8) feet to 520 feet. The majority of the water wells plotted are shallow, less than 50 feet in depth, and correspond to either groundwater monitoring wells or recovery wells; the wells deeper than 50 feet are classified as residential, irrigation, and agriculture.

Based on the driller's log provided on the GW-1 form, "green rock" was encountered in the CMB at depths of 190 feet to 215 feet and "grey rock/black rock" was encountered at depths of 200 feet to 250 feet. Although helpful, using these records alone was not conclusive for determining basement rock depth, as some of the GW-1 forms lacked sufficient, descriptive information. Of the 374 wells in the footprint, only eight reached some type of hard rock. The depths of the wells reaching some type of hard rock ranged from zero feet to about 215 feet. All the other wells appear to have reached a total depth within the unconsolidated Coastal Plain strata.

Drilling results

Drill hole locations are shown in **Figs. 6, 7**; latitude and longitude coordinates are listed in **Table 1**. **Fig. 6** shows drilling locations along with the CMB aeromagnetic low and county outlines. Five state land parcels were selected for drilling. Of the five locations selected, three were drilled taking into account the available budget and time required to complete this project and funds required for another drilling project in the Dan River basin, Stokes Co., North Carolina, before the end of the state fiscal year on 30 June 2015 (**Fig. 7**).

Drill hole names (e.g., CU-C-1-15) are CU = Cumberland County (HO = Hoke; SC = Scotland) followed by C (core hole), 1 (ascension number for that country in the present year), and 15 (year the hole was drilled (also see **Nickerson and Hoffman, 1988**). Thus CU-C-1-15 is the name of the first core hole drilled in 2015 in Cumberland County in the NCGS' database and repository. Drilling results follow (**Table 1**).

Table 1: **Drill hole results – Cumberland-Marlboro 'basin', May-June 2015.**

Drill hole	**Latitude**	**Longitude**	**Elevation above sea level (feet)**	**Site name**	**Basement depth below surface (feet)**	**Total hole depth (feet)**	**Cored Footage (span & total; feet)**	**Basement rock (field name)**
CU-C-1-15 (See Fig. 7.)	35°1'52.29"N	79°2'25.01"W	165 feet	John E. Pechmann Fishing Education Center (aka "Fish Hatchery"	184.5 feet	225 feet	185-225 (40)	Metavolcanic tuff
HO-C-1-15 (See Fig. 7).	34°59'32.76"N	79°14'35.25W	265 feet	Raeford NCDOT Maint. Yard	202 feet	225 feet	208-255 (47)	Muscovite schist – probably a volcanic tuff
SC-C-1-15 (See Fig. 7.)	34°45'33.94"N	79°29'33.45W	220 feet	Laurinburg Highway Patrol / DMV office	334 feet	384.2 feet	330-384.2 (54)	Metavolcanic tuff or meta-sedimentary rock

Basement drill core descriptions and petrographic information

Basement core field descriptions and corresponding petrographic descriptions follow. Colors are from **Goddard *et al.* (1980)**. Thin section billets were stained to facilitate identification of plagioclase and potassium feldspar (if present), and impregnated with blue epoxy (primarily to hold together the moist bedrock).

CU-C-1-15 - **See Fig. 8 (core); Figs. 9, 10, 11a, b (photomicrographs**).

Core description (field): Metavolcanic tuff (5GY 7/2), foliated. Washed core samples indicate a well foliated rock.

Petrographic description: Foliated chlorite-graphite-muscovite-quartz schist with accessory zircon. The graphite is disseminated and locally clumped. The zircon is rounded and in some cases spherical.

HO-C-1-15 - **See Fig. 12 (core), Figs. 13, 14, 15a, b (photomicrographs).**

Core description (field): Paleosaprolite grading downward into muscovite schist (10 GY 5/2) or possibly a schist with a metavolcanic protolith. Washed core samples indicate a well foliated rock.

Petrographic description: Well foliated graphite-muscovite-quartz schist with accessory zircon. The zircon is rounded. Cross crenulations indicate a complex structural history.

SC-C-1-15 - **See Fig. 16 (core); Figs. 17, 18, 19, 20a, b (photomicrographs).**

Core description (field): Metavolcanic tuff or metasediment (5BG 5/2). Washed core samples indicate a well foliated rock.

Petrographic description: Foliated graphite?-bearing biotite-muscovite quartz schist with accessory rounded zircon. Incipient biotite poikilitically encloses graphite, muscovite and quartz **(Fig. 16)**. Portions of biotites have metamict textures.

Summary and conclusions

Based on recently acquired subsurface cores, the Cumberland-Marlboro 'basin' is not a large strike parallel Triassic rift / lacustrine basin seaward of the Deep River Triassic rift / lacustrine basin as proposed by **Bonini (1964)**, **Bonini and Wollard (1960)**, and accepted by **Milci *et al.* (2012)**.

The CMB basement rocks are metamorphic volcanic and meta-sedimentary (?) rocks that are probably older than Triassic age.

Triassic rift / lacustrine basins are known from drilling elsewhere under North Carolina's coastal plain in Bertie County and Camden County. Their aeromagnetic signature indicates that these basins are likely very small. No lacustrine strata have been identified in the Bertie County basin. In the case of the CMB, the presence of a small Triassic rift / lacustrine basin of comparable size to that of the Bertie County basin or that of Camden County cannot be precluded.

Representative core intervals from each core through the coastal plain strata, and the basement cores, are stored in the North Carolina Geological Survey's core repository in Raleigh, North Carolina. Contact the State Geologist to examine core, cuttings, and drill logs.

Core drilling is a cost effective tool to ascertain the nature of geophysical anomalies beneath thin coastal plain cover.

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Funding for the drilling component of this project was provided by the North Carolina General Assembly (FY 2014-15) to investigate the CMB.

We want to thank the North Carolina Department of Transportation (NCDOT), and in particular, Mr. Charles Vick, Maintenance Engineer for Hoke and Scotland counties, North Carolina, for permission to drill holes in the NCDOT maintenance yards.

We want to thank the North Carolina Wildlife Commission for permission to drill at the John E. Pechmann Fishing Education Center, Fayetteville, North Carolina. This is the location of the Cumberland County “Fish Hatchery” core hole. Mr. Gerald Klauss and Mr. Kris Smith (site manager) provided invaluable information and assistance. Ms. Christina J. Jester of Bill’s Well Drilling Co., Inc. provided a driller’s log for the water well at the John E. Pechmann Fishing Education Center (Cumberland County).

We also want to thank Colonel William J. Grey, commander of the North Carolina State Highway Patrol, for permission to drill at the Laurinburg Highway Patrol station (Scotland County).

Mr. Orus F. Patterson III, Patterson Exploration Services, Inc., Sanford, North Carolina, was the drilling contractor. The Rotasonic holes were drilled by Terra Sonic International in May and early June 2015.

We also thank Matt Merrill and Robert Milici, U.S. Geological Survey, for their thoughtful review.

Fig. 1. Rotasonic drill used for the Cumberland-Marlboro ‘basin’ investigation. This is drill hole site HO-C-1-15 at the Department of Transportation maintenance yard, Hoke County, North Carolina. Rotasonic (sonic drilling) consists of three steps: Step 1 – Advance core barrel using sonic frequencies. This step can be performed using no fluids, air, or mud. Step 2 – Casing override – After the core barrel is in place, casing is sonically advanced over the core barrel to protect the borehole’s integrity in loose unconsolidated ground. Step 3 – Core retrieval – The core barrel is retrieved, producing a relatively undisturbed sample with near 100% core recovery. Steps 1-3 are repeated to depth.

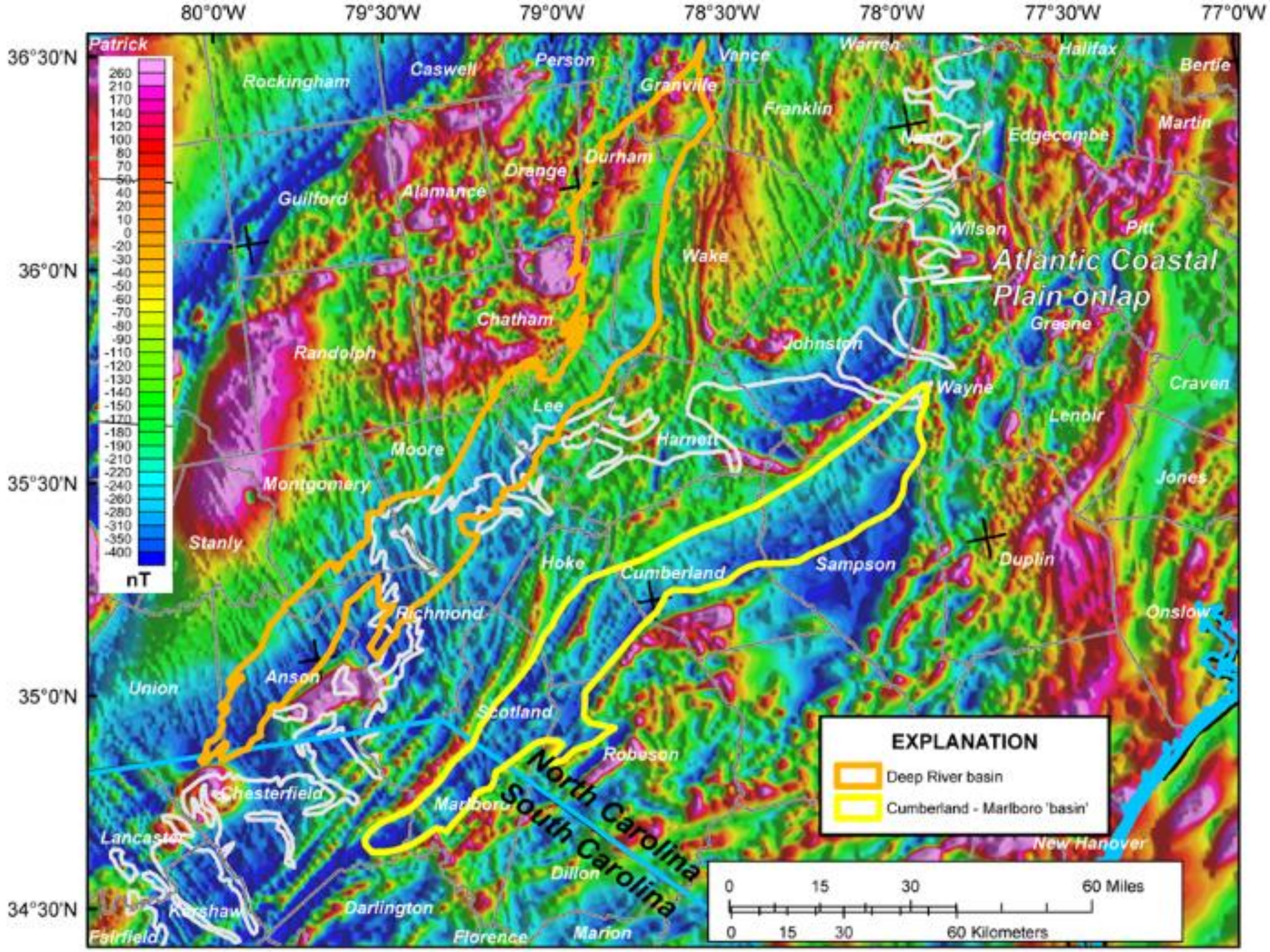

Fig. 2. Map showing the location of the Cumberland-Marlboro 'basin' aeromagnetic anomaly. Map contoured in nanoteslas (nT), a measurement of the strength of a magnetic field.

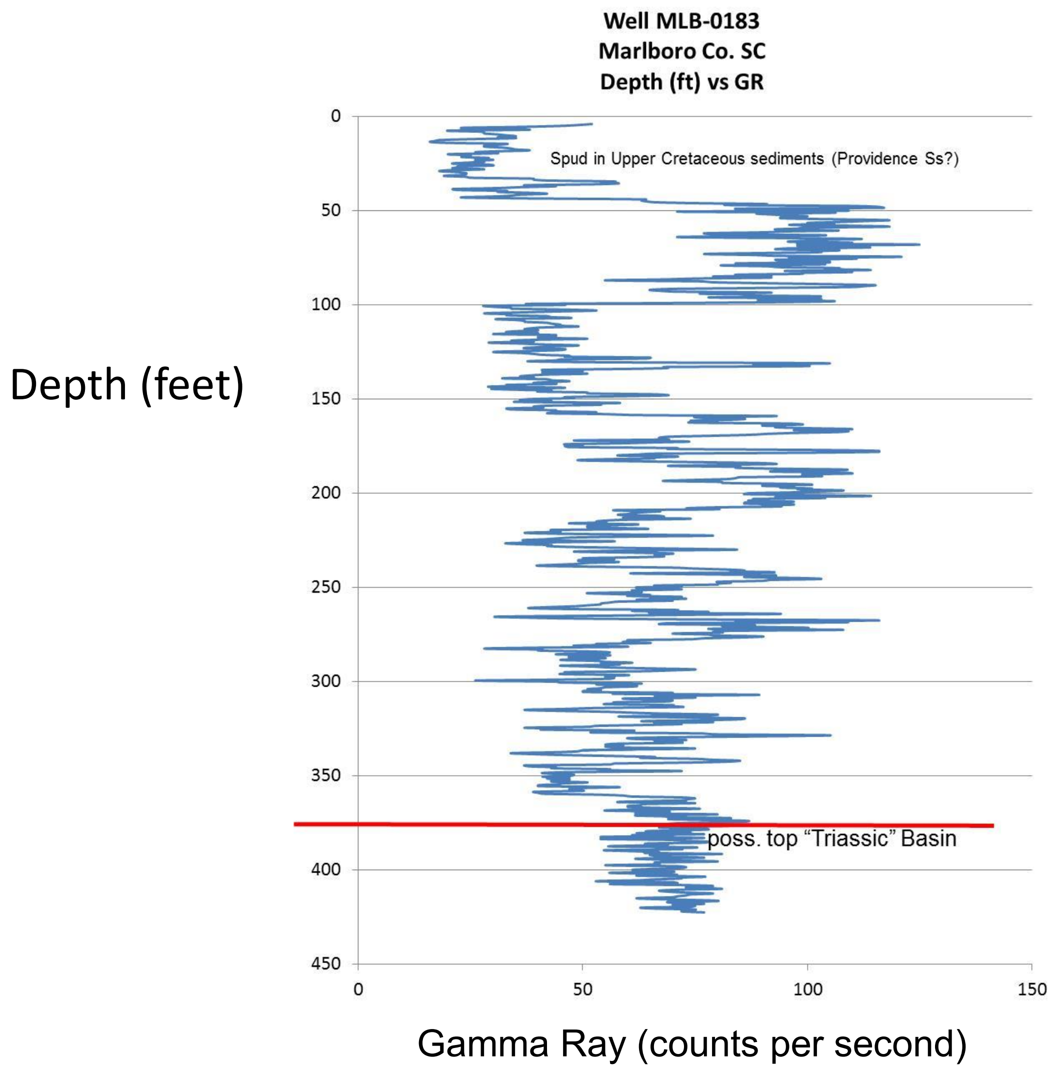

Fig. 3. Well MLB-0183, Marlboro County, South Carolina showing gamma-ray counts *vs*. depth.

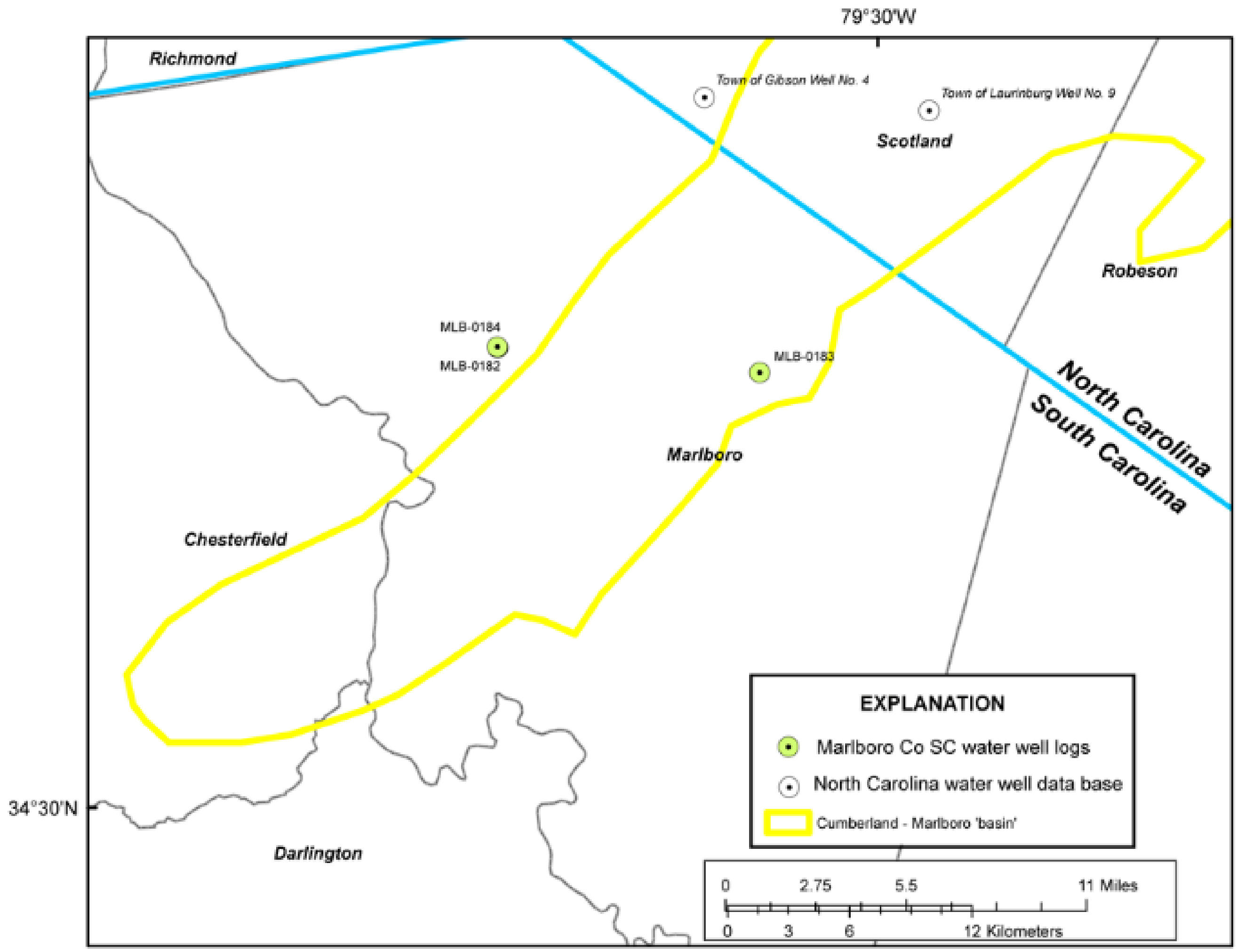

Fig. 4. Map showing location of two South Carolina water wells.

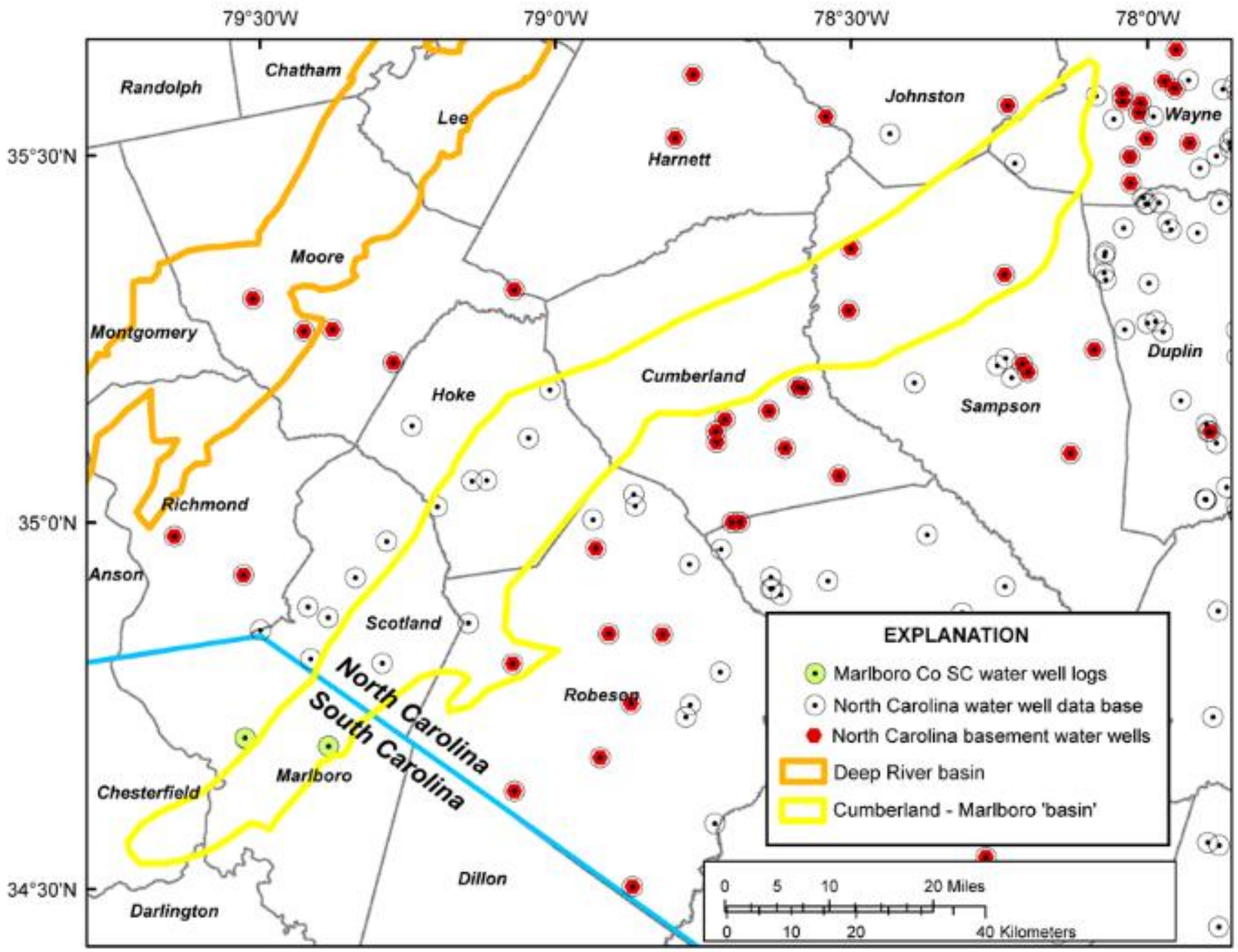

Fig. 5. Map showing the North Carolina wells that penetrate basement rocks. The Cumberland-Marlboro 'basin' footprint is shown in yellow. The limited water well locations are from the on-line Department of Environmental Quality's, Division of Water Resources database at URL http://www.ncwater.org/?page=20. A more extensive set of water wells (GW-1 database not publically accessible) is in the same footprint area is shown in Figure 6.

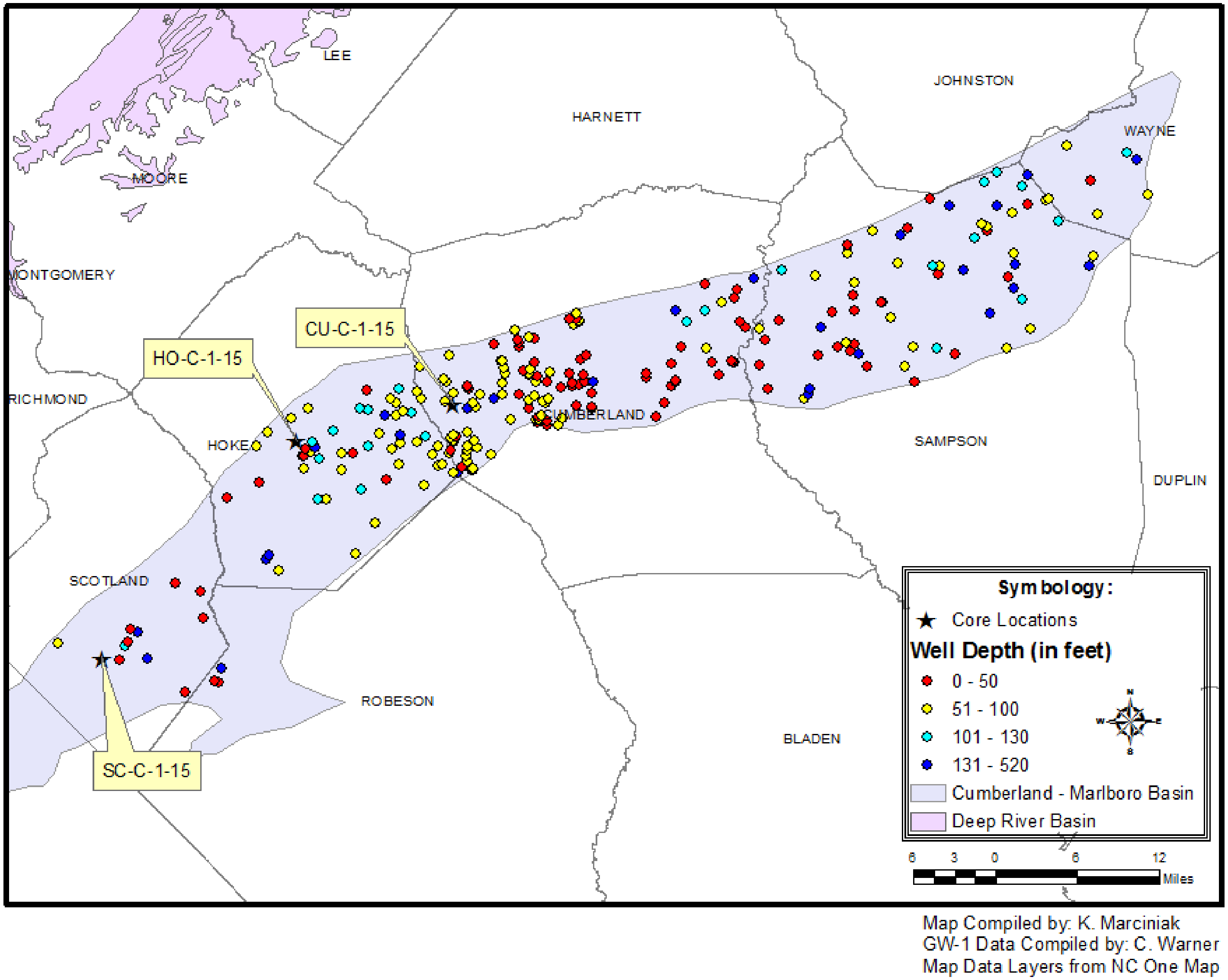

Fig. 6. Cumberland-Marlboro 'basin' groundwater wells in the GW-1 state database. Well depths are a proxy for coastal cover thickness. The location of the three drill holes from this study are shown on the figure.

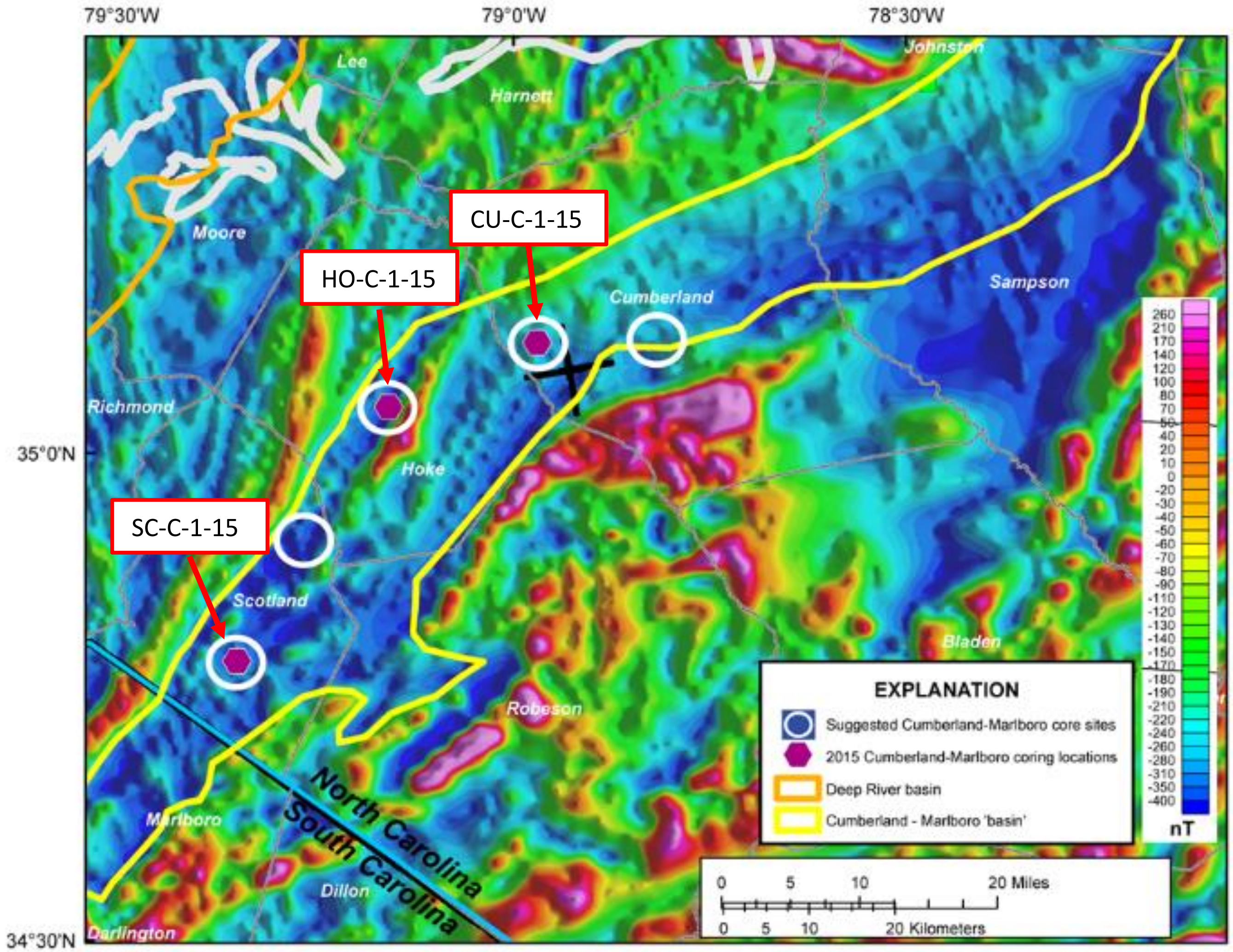

Fig. 7. Map showing aeromagnetic anomaly and project core hole locations. Map contoured in nanoteslas (nT).

Fig. 8. Basement core photographs of core hole CU-C-1-15: (top) depth 220.5 feet; (bottom) depth 225 feet.

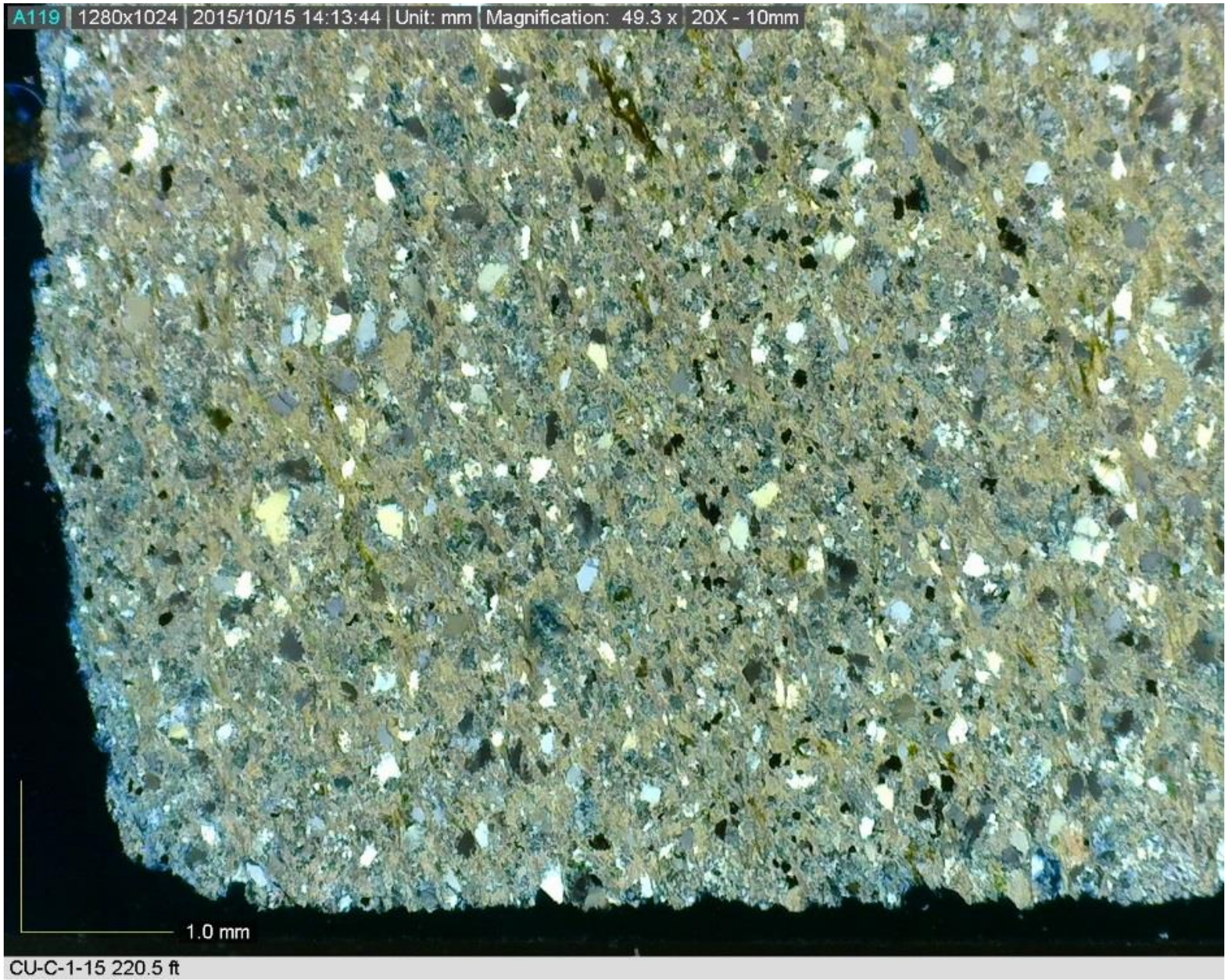

Fig. 9. Basement core photomicrograph of core hole CU-C-1-15: depth 220.5 feet. Magnification ~50x (wide field). This view shows a penetrative metamorphic fabric better shown in subsequent figures. Scale bar embedded in the figure.

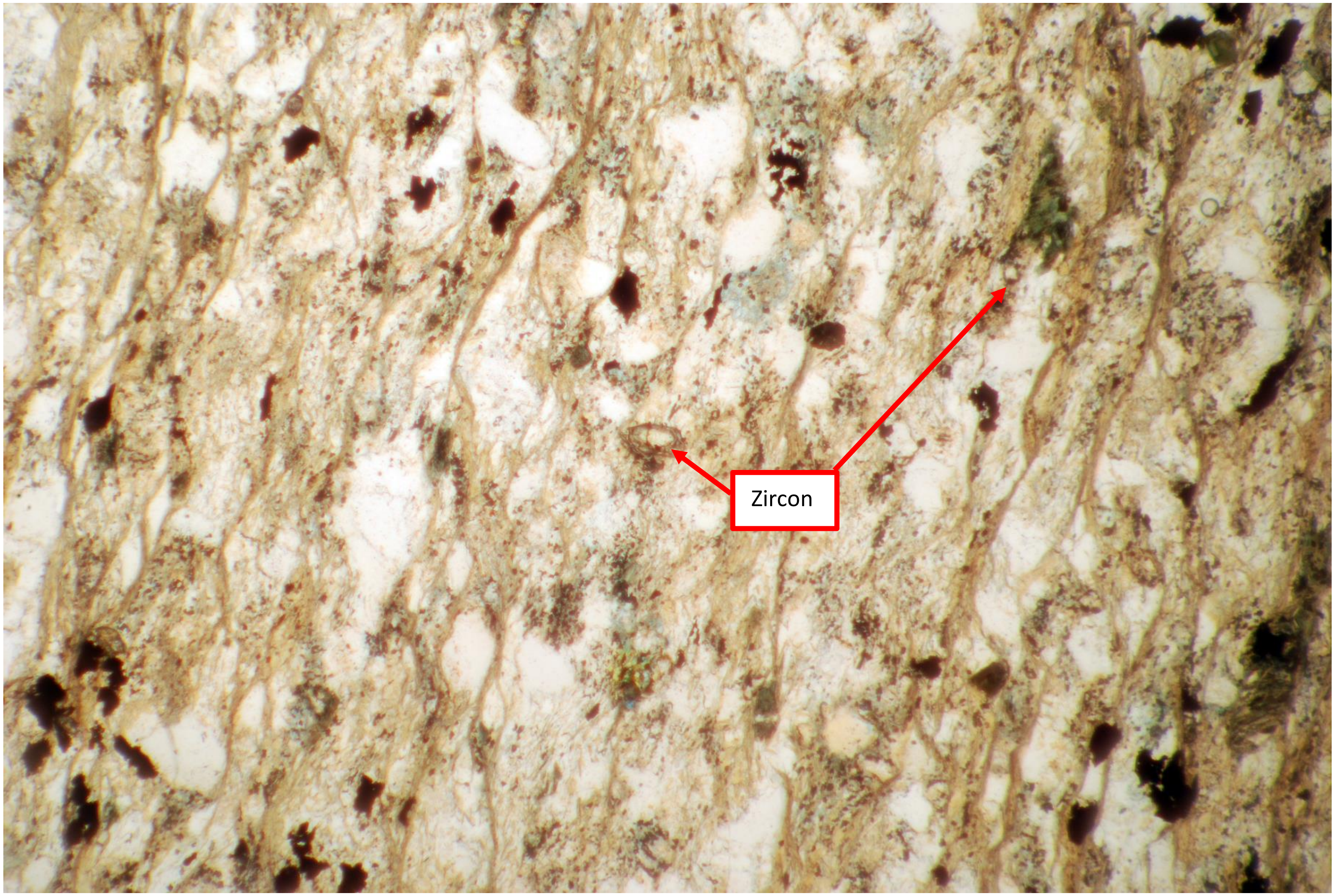

Fig. 10. Photomicrograph of basement rocks in core hole CU-C-1-15, depth 218 feet. Plane light, 40x; field of view width is about 28 mm. A metamorphic foliation penetrates the rock. Quartz and subordinate feldspars and fine-grained metamorphic minerals with accessory biotite and some magnetite (?) comprise this rock. Trace amounts of rounded zircons (center of field of view) with possible overgrowths suggest a metasedimentary protolith.

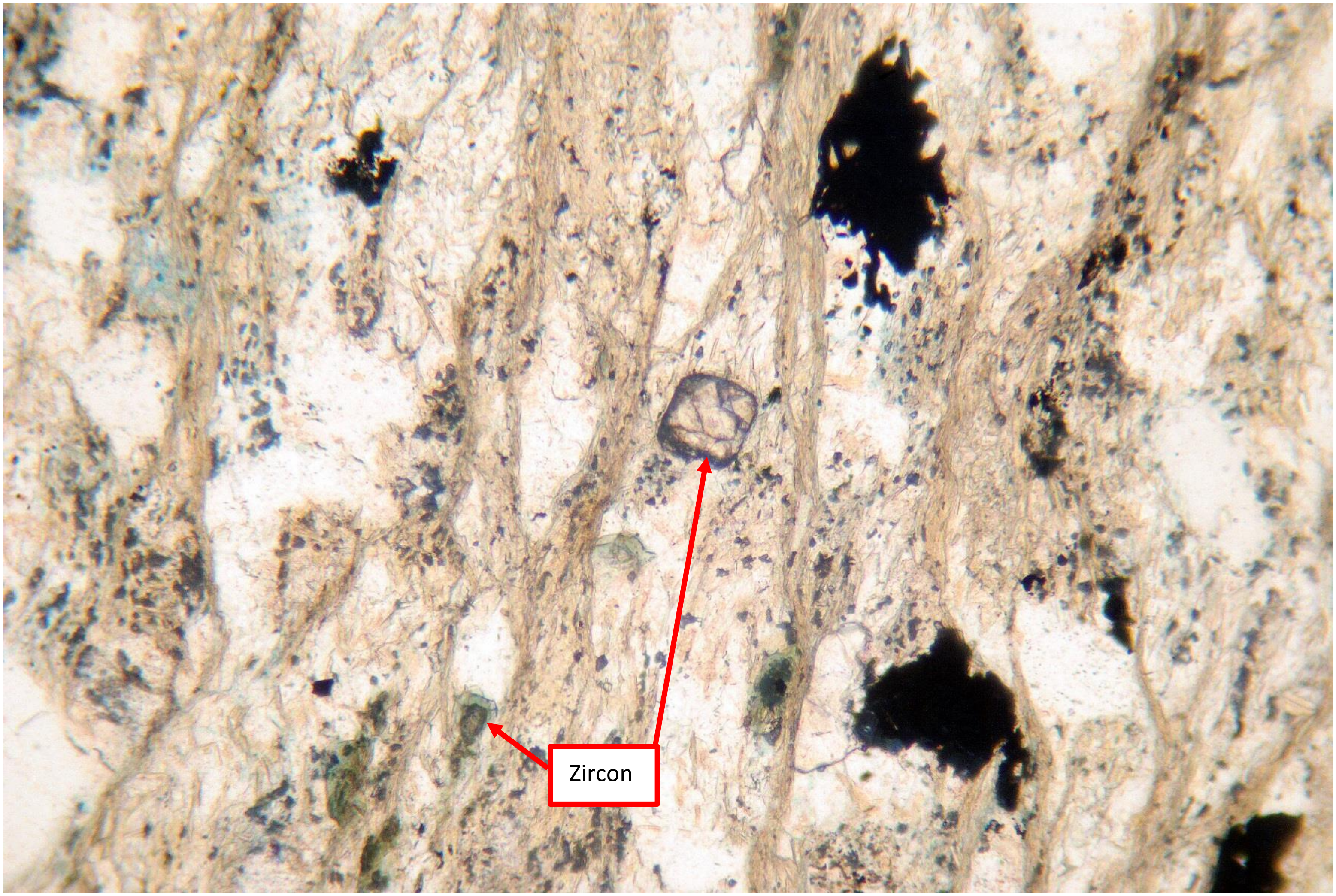

Fig. 11a. Photomicrograph of basement rocks in core hole CU-C-1-15, depth 218 feet. Plane light, 100x; field of view width is about 10 mm. A metamorphic foliation penetrates the rock. Quartz and subordinate feldspars and fine-grained metamorphic minerals with accessory biotite and some magnetite (?) comprise this rock. Trace amounts of rounded zircons (center of field of view) with possible overgrowths suggest a metasedimentary protolith.

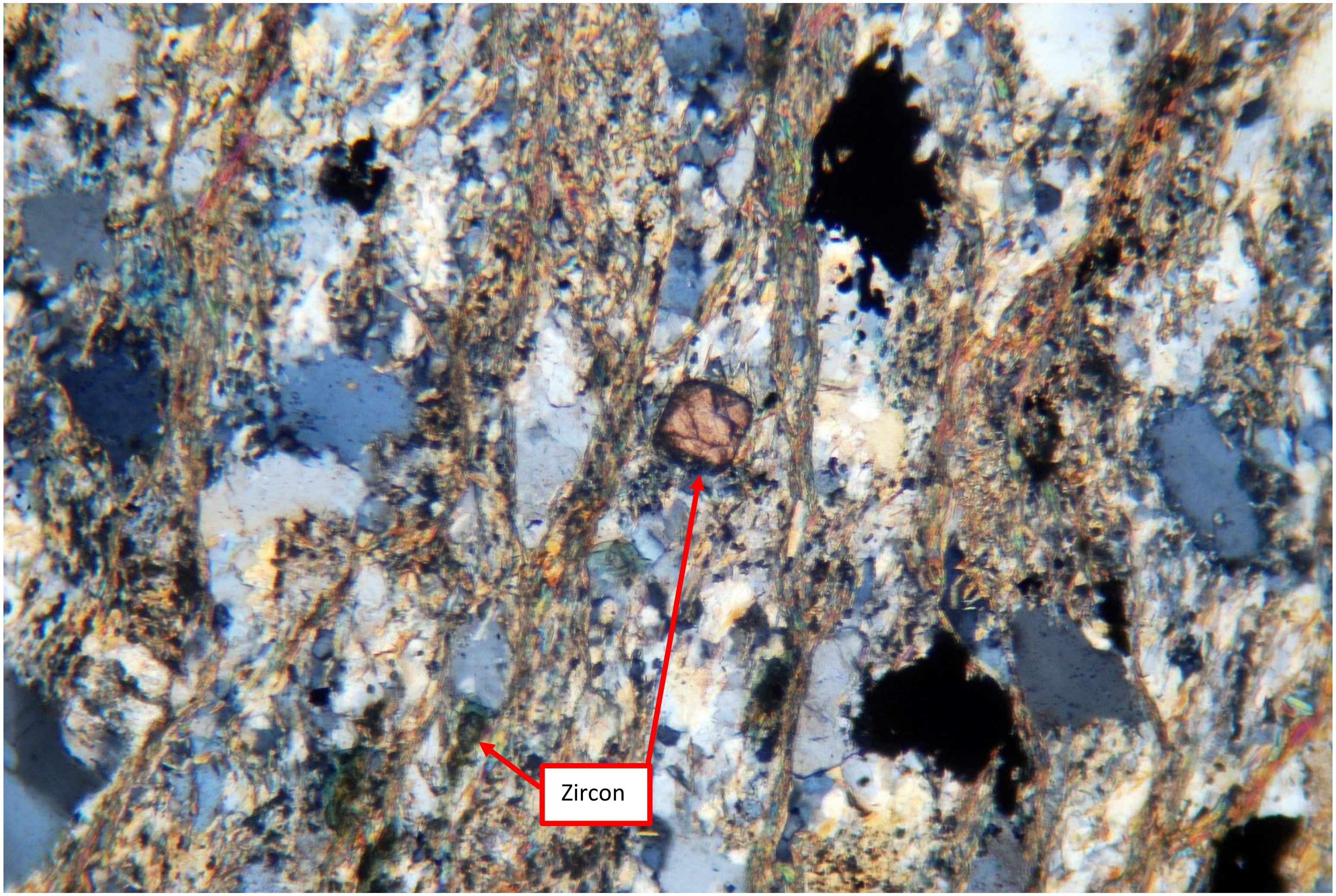

Fig. 11b. Photomicrograph of basement rocks in core hole CU-C-1-15, depth 218 feet. Cross polarized light, 100x; field of view width is about 10 mm. A metamorphic foliation penetrates the rock. Quartz and subordinate feldspars and fine-grained metamorphic minerals with accessory biotite and some magnetite (?) comprise this rock. Trace amounts of rounded zircons (center of field of view) with possible overgrowths suggest a metasedimentary protolith.

Fig. 12. Basement core photograph of core hole HO-C-1-15: (top) depth 246 feet; (bottom) depth 250 feet.

Fig. 13. Basement core photomicrograph of core hole HO-C-1-15: depth 246 feet. Magnification ~50x (wide field). The distinctive metamorphic crenulations of the metamorphic foliation are clearly shown. Well foliated quartz-muscovite schist with accessory graphite and magnetite (?). The foliation is crenulated suggesting slip. Scale bar embedded in the figure.

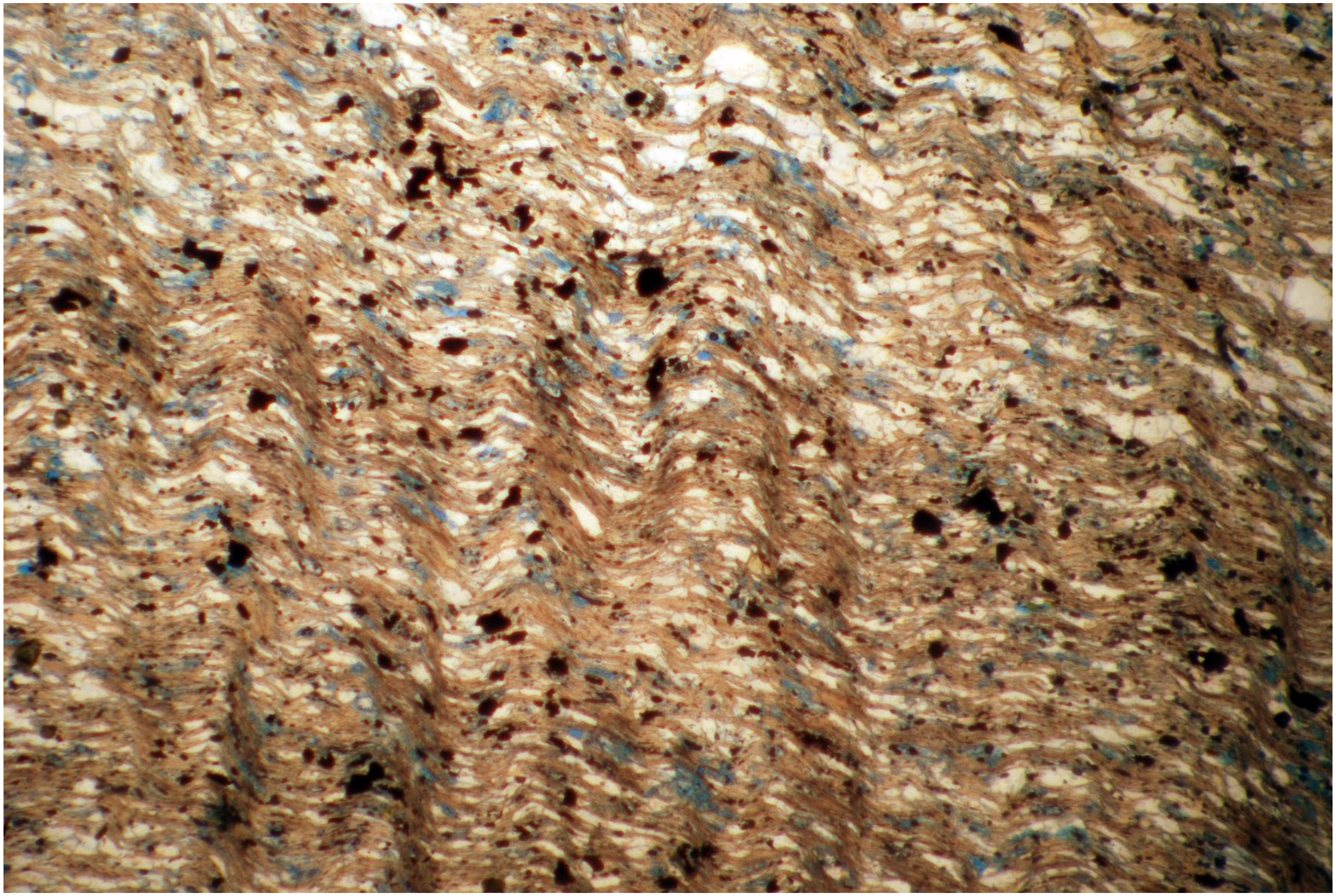

Fig. 14. Photomicrograph of basement rocks in core hole HO-C-1-15, depth 227 feet. Plane light, 40x; field of view width is about 28 mm. The distinctive metamorphic crenulations of the metamorphic foliation are clearly shown. Well foliated quartz-muscovite schist with accessory graphite and magnetite (?). The foliation is crenulated suggesting slip.

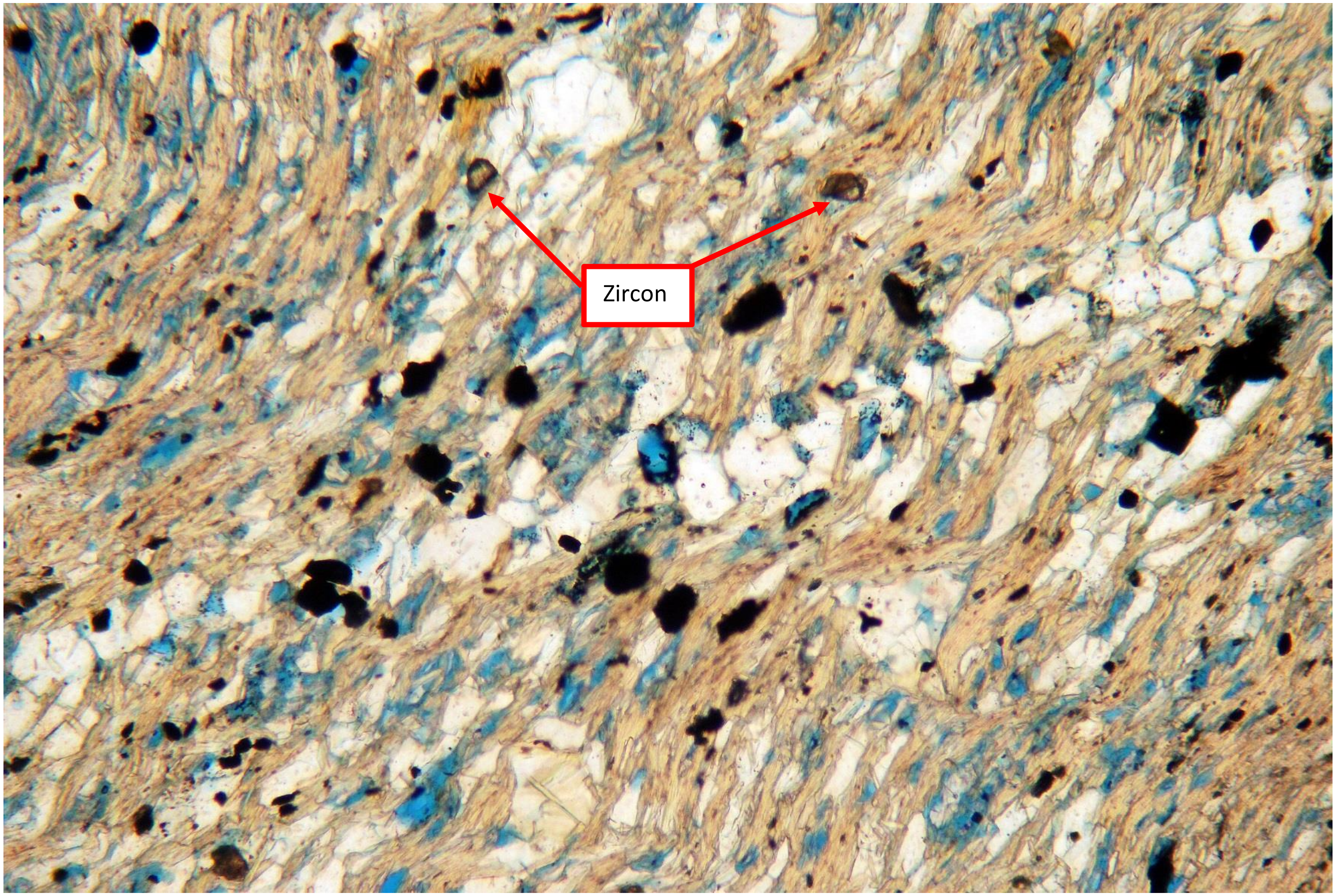

Fig. 15a. Photomicrograph of basement rocks in core hole HO-C-1-15, depth 247.5 feet. Plane light, 100x; field of view width is about 10 mm. The distinctive metamorphic crenulations of the metamorphic foliation are clearly shown. Well foliated quartz-muscovite schist with accessory graphite and magnetite (?). The foliation is crenulated suggesting slip.

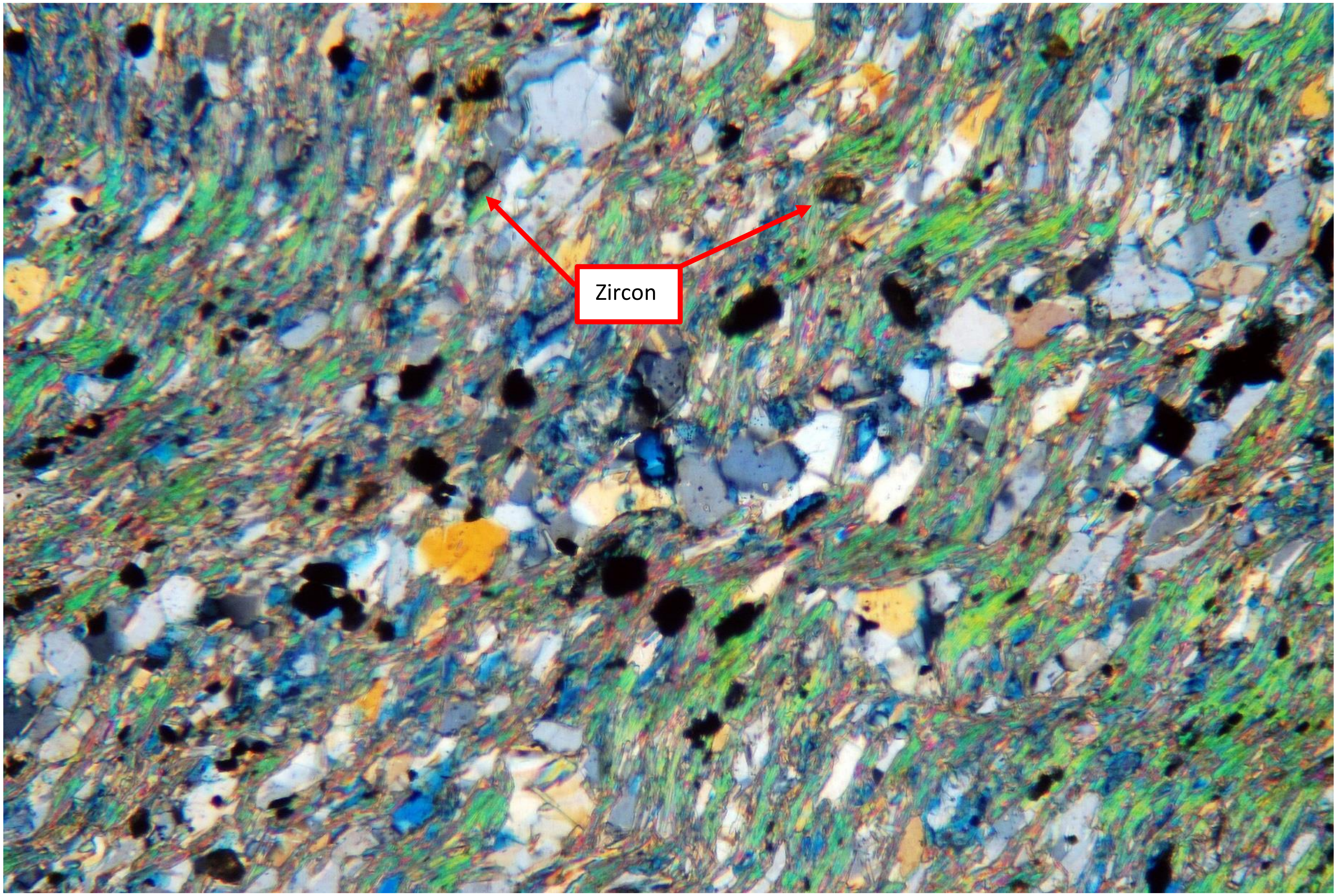

Fig. 15b. Photomicrograph of basement rocks in core hole HO-C-1-15, depth 247.5 feet. Cross polarized light, 100x; field of view width is about 10 mm. The distinctive metamorphic crenulations of the metamorphic foliation are clearly shown. Well foliated quartz-muscovite schist with accessory graphite and magnetite (?). The foliation is crenulated suggesting slip.

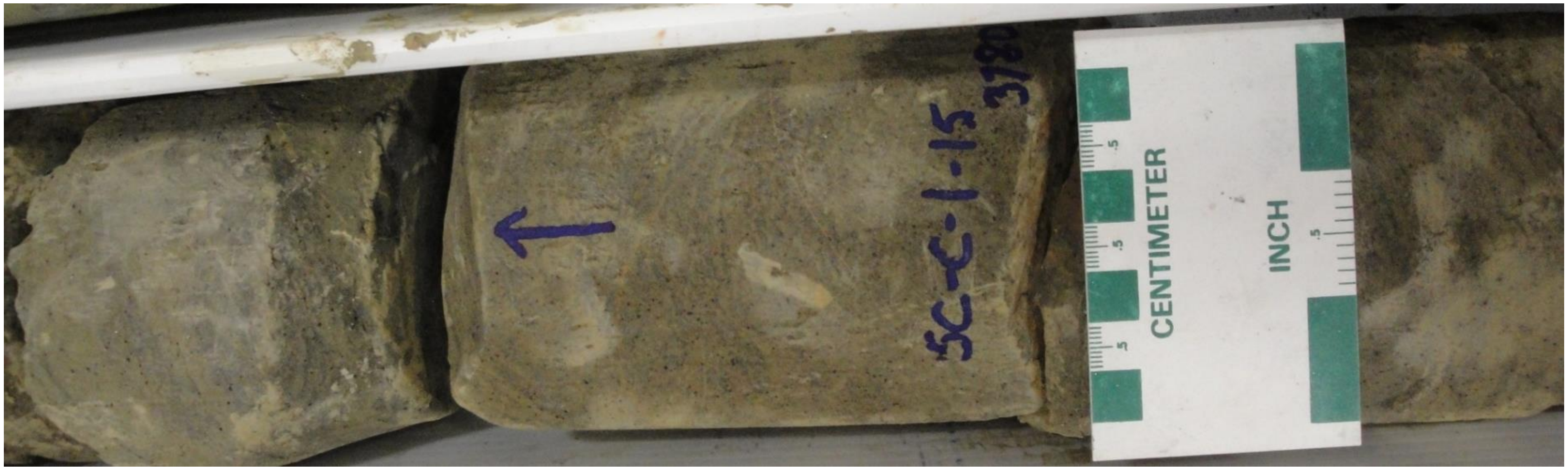

Fig. 16. Basement core photograph of core hole SC-C-1-15: (top) depth 378.0 feet; (bottom) depth 384.2 feet.

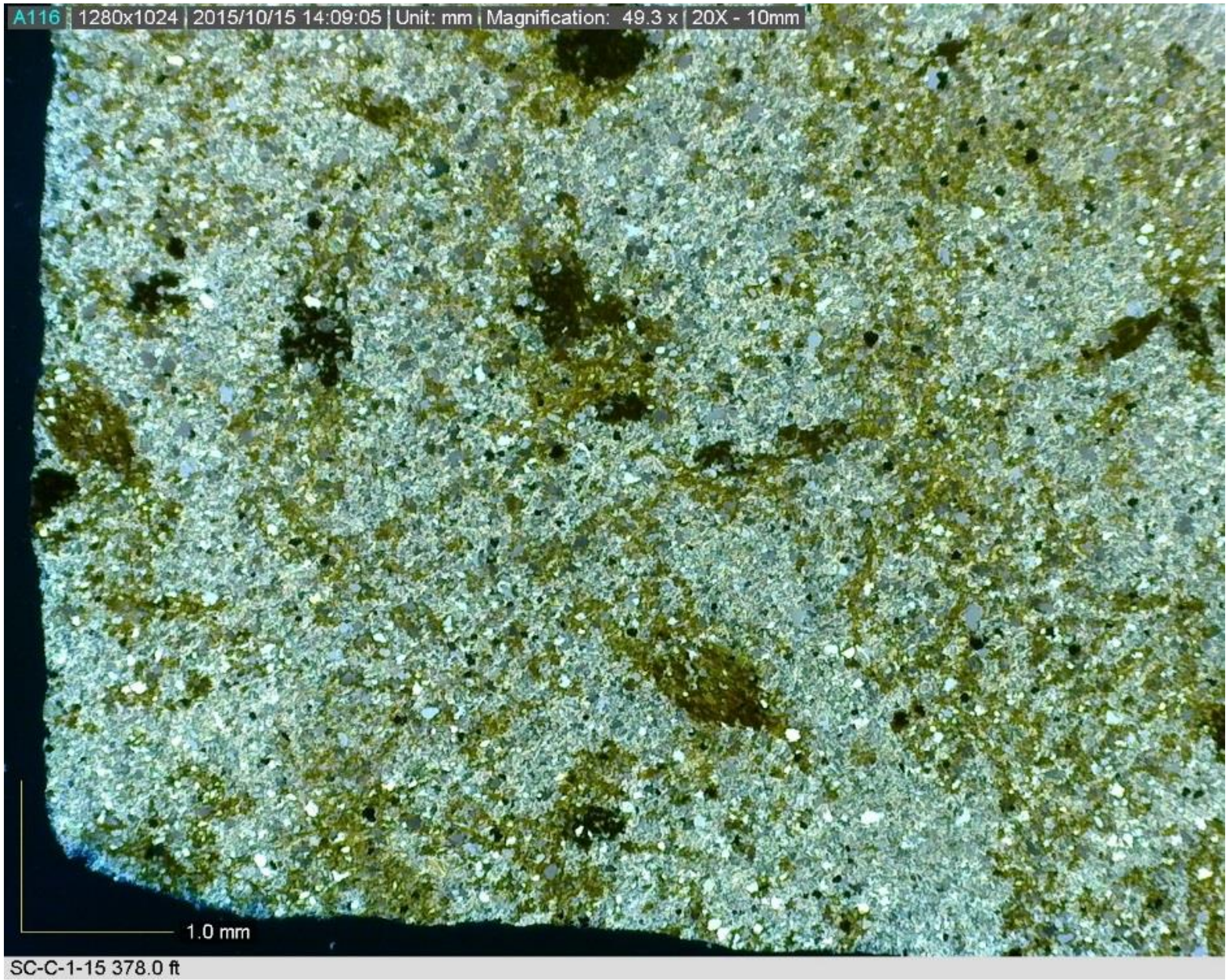

Fig. 17. Basement core photomicrograph of core hole SC-C-1-15: depth 378.0 feet. Magnification ~50x (wide field). Large poikilitic clots of biotite appear to replace chlorite. Quartz and feldspar are other framework minerals. Accessory magnetite and graphite (?) are present. Compositional banding and foliation are evident in this image. Scale bar embedded in the figure.

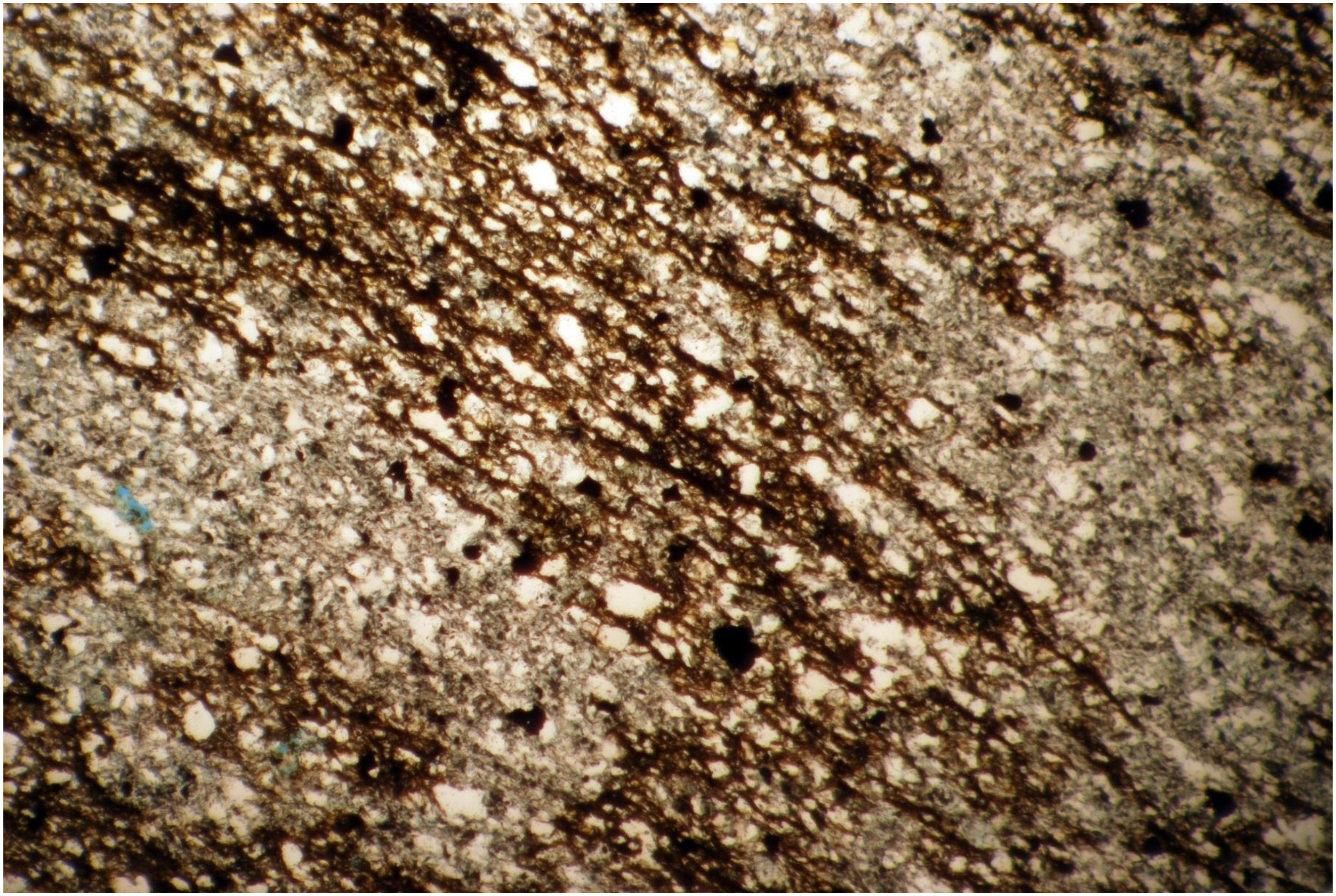

Fig. 18. Photomicrograph of basement rocks in core hole SC-C-1-15, depth 384.4 feet. Plane light, 40x; field of view width is about 28 mm. Well foliated quartz biotite schist with accessory graphite (?) and magnetite.

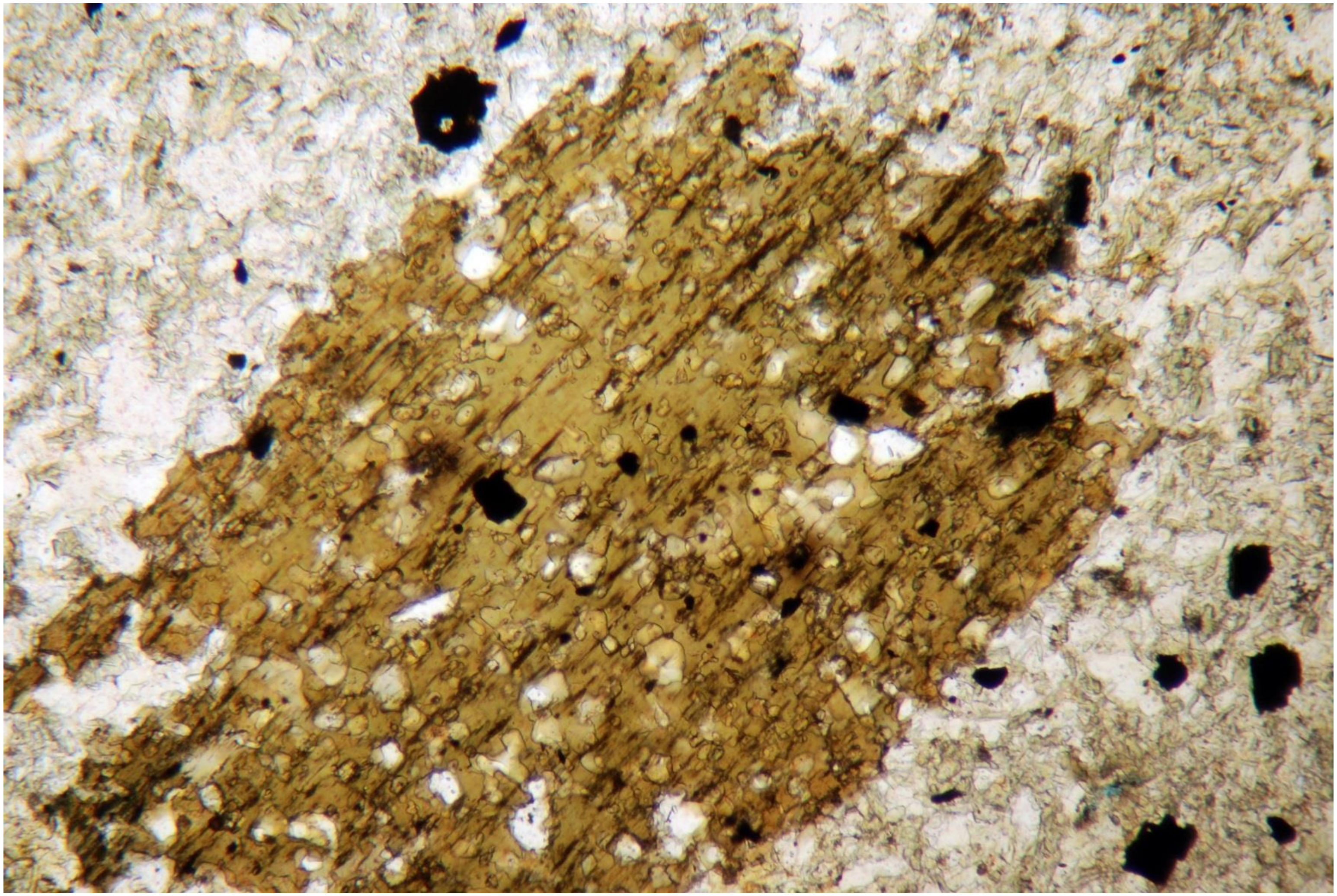

Fig. 19. Photomicrograph of basement rocks in core hole SC-C-1-15, depth 384.4 feet. Plane light, 100x; field of view width is about 10 mm. Poikolitic biotite replaces chlorite (?) and surrounds quartz. The opaque black minerals are thought to be magnetite. Quartz, fine-grained feldspar, and chlorite comprise the remainder of the rock. Metamict texture is visible in the biotite (left center and center of field of view).

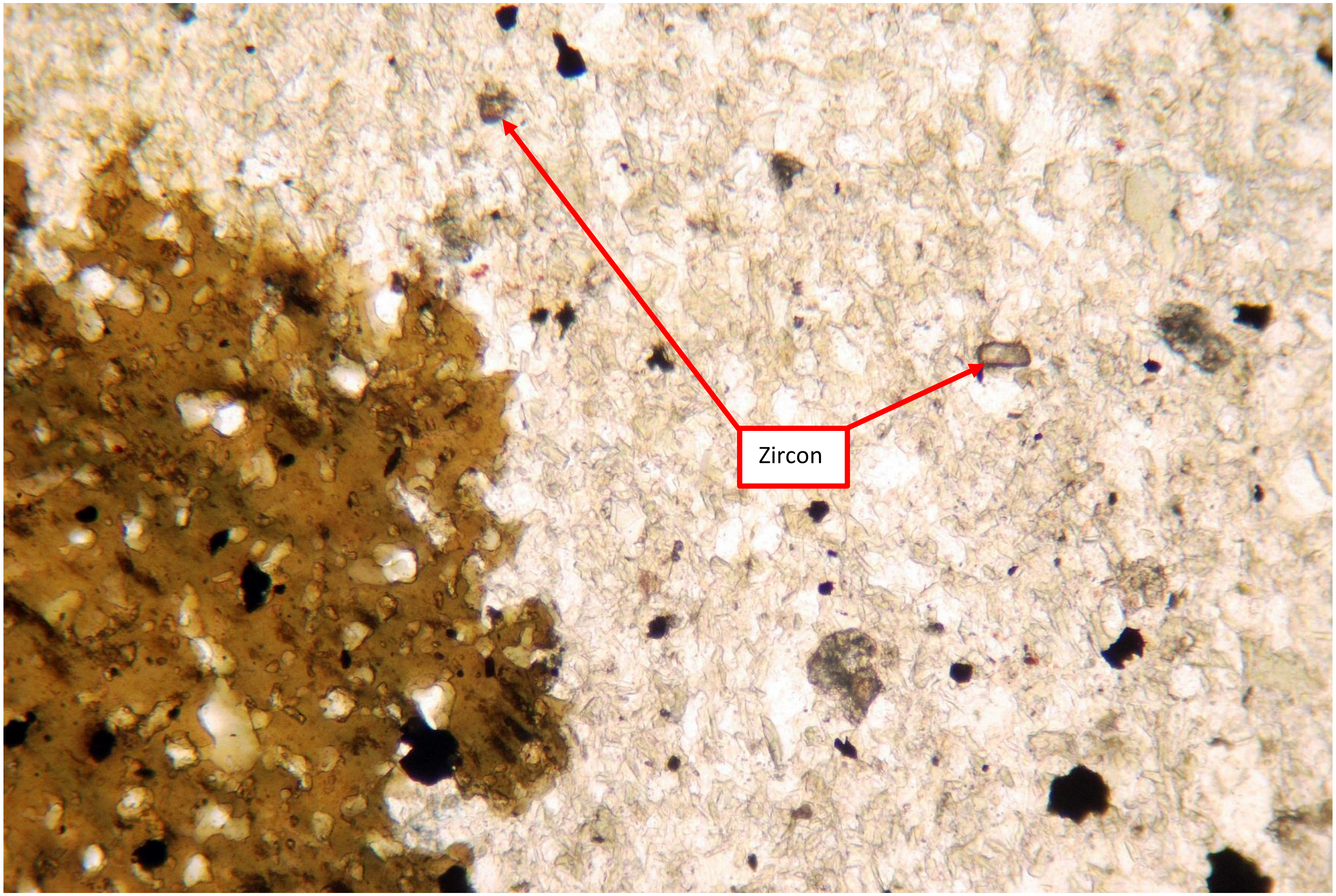

Fig. 20a. Photomicrograph of basement rocks in core hole SC-C-1-15, depth 384.2 feet. Plane light, 100x; field of view width is about 10 mm. Rounded zircons are present throughout the field of view.

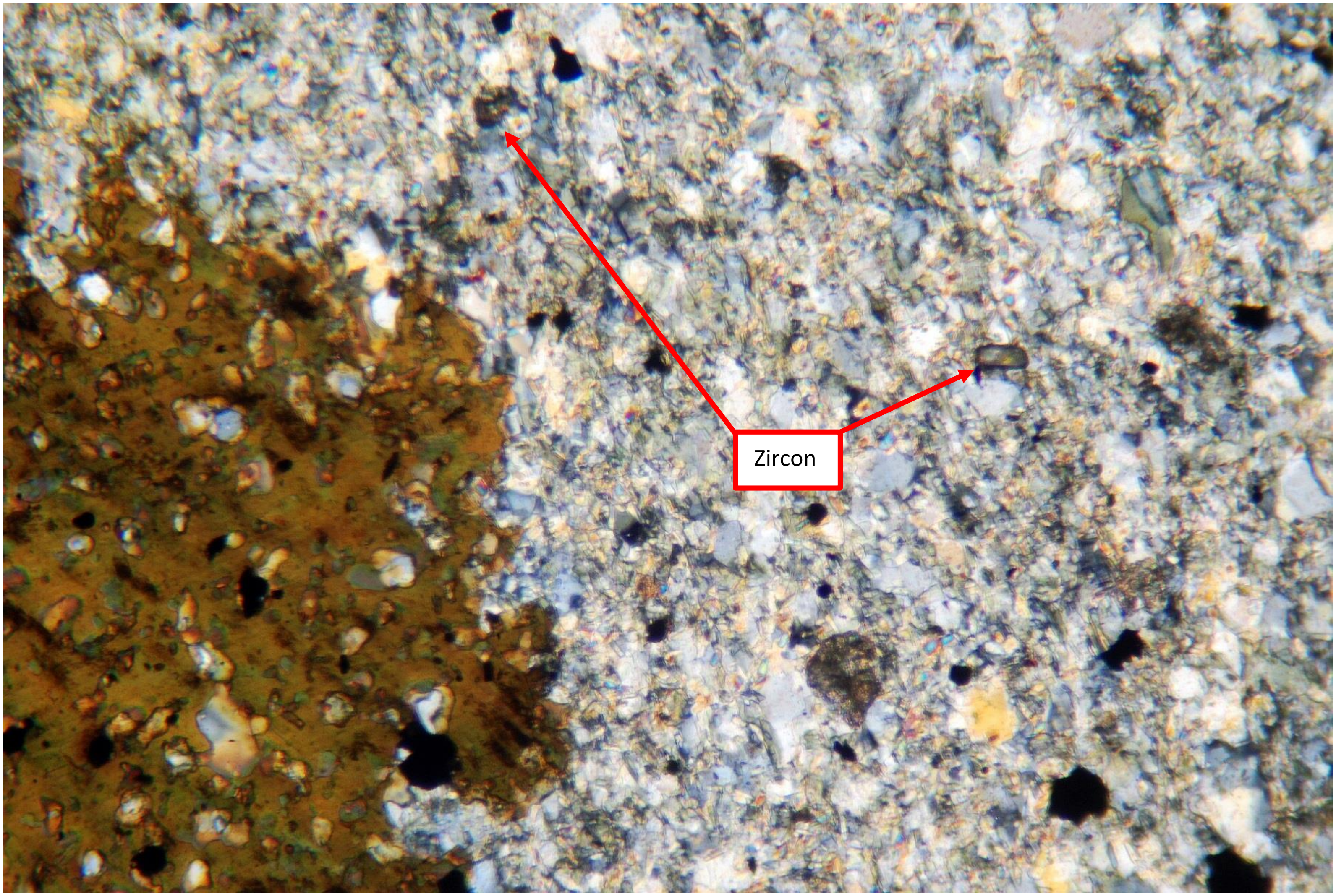

Fig. 20b. Photomicrograph of basement rocks in core hole SC-C-1-15, depth 384.2 feet. Cross polarized light, 100x; field of view width is about 10 mm. Rounded zircons are present throughout the field of view.