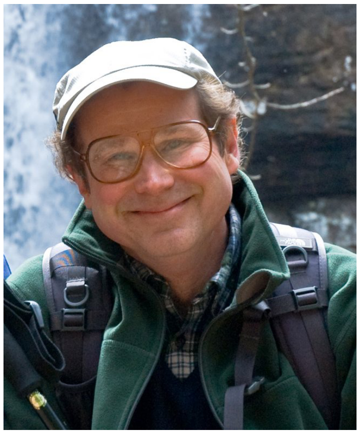
Robert B. Hawman

Professor & Undergraduate Advisor



B.S.	Dickinson College
M.S.	Pennsylvania State University
Ph.D.	Princeton University

Postdoctoral Research Associate, University of Wyoming, 1986-1990

Teaching

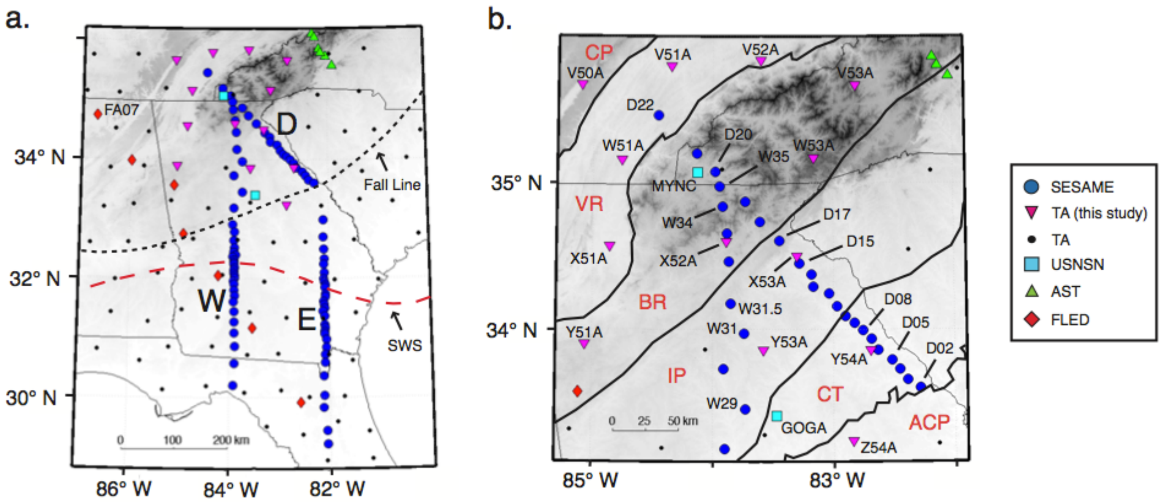
Awards: *J. Hatten Howard, III Honors Teaching Award, April 27, 2005*
Franklin College of Arts & Sciences, Outstanding Academic Advisor Award for 2013

Courses: Honors 2080H: *Honors Science*
Geol 1250: *Physical Geology*
Geol 4600/6600: *Solid Earth Geophysics*
Geol 4620/6620: *Exploration Geophysics*
Geol 8030: *Advanced Topics in Geophysics*
Geol 8250: *Plate Tectonics*
Geol 8600: *Topics in Seismology*

Research Interests

Ongoing field studies in the Southern Appalachians include broadband profiling across the Blue Ridge Mountains and the Alleghanian suture between Laurentian and Gondwanan lithosphere, wide-angle reflection profiling of the crust and upper mantle using quarry blasts, electrical resistivity and shallow surface-wave profiling of karst, resistivity profiling of landslides, shallow reflection profiling across major fault zones and barrier islands, and monitoring of regional seismicity.

SESAME: Southeastern Suture of the Appalachian Margin Experiment



a. Regional map of the southeastern United States showing the SESAME array (W, E, D), the U. S. Transportable Array (TA), and other regional broadband deployments. The Suwannee-Wiggins suture (SWS), roughly corresponding to the Brunswick magnetic anomaly, marks the proposed juxtaposition of Laurentian and Gondwanan lithosphere. FLED: Florida-to-Edmonton deployment, including station FA07 *(French et al., 2009)*; AST: Appalachian Seismic Transect *(Wagner et al., 2012)*; USNSN: U. S. National Seismic Network.

b. CP: Cumberland Plateau; VR: Valley & Ridge; BR: Blue Ridge; IP: Inner Piedmont; CT: Carolina terrane; ACP: Atlantic Coastal Plain. (after *Parker et al., 2013*).

SESAME (2010-2014) involved the deployment of an 85-station network of broadband seismometers across a portion of the southern Appalachians. This was a cooperative project involving investigators at Brown University (Karen M. Fischer and Donald Forsyth) and University of North Carolina, Chapel Hill (Lara S. Wagner, now at Carnegie Institution for Science, Dept. of Terrestrial Magnetism). The principal aim of this experiment, which was funded through the EARTHSCOPE program of NSF, was to image the proposed late Alleghanian suture between Laurentian and Gondwanan lithosphere, possibly marked by the Brunswick magnetic anomaly and a series of prominent, south-dipping reflections penetrating the entire crust on COCORP seismic reflection profiles. The broadband data are being used to test models for the suture in the subcrustal lithosphere (*Fischer et al., 2010; Wagner et al., 2011*). The main question here is how the mantle responded mechanically during the final stages of collision and subsequent rifting: did it fail along a localized, gently-dipping shear zone, or along a much broader zone with strain distributed over a much greater volume of rock? Another question focuses on the nature of the mechanisms responsible for the root zone recently observed beneath high topography of the Blue Ridge Mountains and Valley and Ridge (*Hawman, 2008; French et al., 2009; Baker & Hawman, 2011; Hawman et al., 2012; Parker et al., 2013; Verellen et al., 2020).*

Brasstown Bald (elevation: 4784 ft) and adjacent peaks in the Blue Ridge Mountains of Georgia.

We began our deployment in 2010 with a 7-station test array. These stations were installed on cement piers; at one station we installed a second instrument using the "direct-burial" method (sand base; no pier) for comparison (*Parker et al., 2011*). Based on the strong similarity of waveforms observed for those two instruments, we switched to direct-burial for subsequent installations in 2011 (36 instruments) and 2012 (42 instruments).

Our initial data analysis focused on average crustal properties of terranes northwest of the Coastal Plain. Well constrained estimates of average crustal Vp/Vs indicate that the average crustal composition of the Carolina Terrane is more felsic than intermediate, suggesting that volcanic arc rocks exposed at the surface are underlain by more granitic basement, possibly a southeastward extension of Grenville crust (*Parker et al., 2013*).

Ps receiver functions also confirm the existence of a significant root beneath the highest elevations of the Blue Ridge Mountains, in agreement with previous wide-angle results (see below), and have mapped the extent of the root along strike. To explain the disparity between significant relief on the Moho and the planar configuration of the overlying Alleghanian detachment (*Hawman et al., 2012*), we suggest that the present root is a remnant of a much broader region of thickened crust developed across the orogen in response to Alleghanian thrust loading (*Parker et al., 2013; 2016*). According to this model, during Mesozoic extension, the combination of thickened crust and heating by mafic intrusions and/or underplating triggered thinning of the lower crust by lateral flow, allowing rebound of the Moho without significant warping of the overlying Alleghanian detachment. Extension and crustal thinning were concentrated beneath outboard terranes, leaving the crust beneath the Blue Ridge largely intact. Alternatively, the deep structures may be partly related to thickening inherited from Grenville continental collision.

Receiver functions for these terranes contain frequencies high enough to allow resolution of velocity contrasts associated with rocks of the Alleghanian detachment (*Parker et al., 2015*). Forward modeling of amplitudes and polarities of *Ps* waveforms is consistent with a package of metamorphosed carbonates and sandstones underlying the Blue Ridge – Inner Piedmont allochthon.

We also image a SE-dipping boundary interpreted as a low-angle fault contact between the Inner Piedmont and Carolina Terrane.

Beneath the Coastal Plain, very low-velocity sediments generate multiples that overwhelm *Ps* conversions from the lower crust and mantle. Here we have used wide-angle reflections (*SsPmp*) to image the Moho and to estimate average *P*-wave velocity of the crust (*Parker et al., 2016*). These reflections and *PpPmp* arrivals (*Clements et al., 2019*; *Rice et al., 2019; Rice, 2019*) are strong enough to observe (even at precritical angles) without stacking records for multiple earthquakes.

Currently we are using *PKIKP (PKPdf;* P waves that travel through the inner core) as a virtual source to construct broadband images of P-wave reflectivity of the crust and upper mantle, including the lithosphere/asthenosphere boundary (LAB), beneath the central and eastern U.S. (*Verellen et al., 2020; Hanawalt et al., 2024*). Arrivals interpreted as reflections from the Moho increase in two-way time from ~10 s beneath the Georgia coastal plain to 17.4 s (~57 km) beneath the Blue Ridge Mountains. These are the first observations of normal-incidence P-wave reflections from the Moho beneath the higher elevations of the southern Appalachians. They are consistent with earlier studies showing a correlation between elevation and crustal thickness (*Hawman, 2008; French et al., 2009; Parker et al., 2013, 2016; Hopper et al., 2016*). This has been used to estimate the density contrast between lower crust and upper mantle and suggests that mountain topography is in rough isostatic equilibrium (*Hawman et al., 2012; Schmandt et al., 2015*).

Reflections at 32-36 s (120 – 135 km) are consistent with the depth to the LAB found in recent inversions of Ps arrivals and surface waves. Alternatively, these and later reflections may be due to layering associated with drag-induced flow in the asthenosphere, suggesting largely horizontal rather than vertical flow for depths less than 225 km beneath the Georgia coastal plain (*Verellen et al., 2020*).

Extending this analysis to include USArray stations beneath the central U.S. reveals distinctive patterns of P-wave reflectivity within the uppermost mantle (*Hanawalt et al., 2024*). The overall distribution of reflections identified objectively using the sign test statistic applied to bootstrapped stacks is consistent with a westward increase in depth of the lithosphere-asthenosphere boundary (LAB) from roughly 110 to 250 km that is marked within the lower lithosphere by piecewise-continuous segments of elevated horizontal reflectivity. We suggest that the vertical change in horizontal reflectivity straddles the lithosphere-asthenosphere transition, encompassing a broad zone of layering caused by increased strain in the lower lithosphere as well as drag-induced flow in the asthenosphere.

Scenes from our station installations in 2010 and 2011. Left: Davison Hogan (UGA), Sarah Hanson-Hedgecock (UNC-Chapel Hill), and Horry Parker (UGA). Right: Hamilton Goodner (UGA) and Ved Lekic (Brown; now at University of Maryland).

Karen Fischer (Brown) and Pnina Miller (PASSCAL)

Abby Saenger (UGA), Jacqui Maleski (UGA), Julia Macdougall (Brown), Lara Wagner (Chapel Hill), Karen Fischer (Brown), Ved Lekic (Brown), and Sarah Hanson-Hedgecock (Chapel Hill).

As part of this study, we have also participated in "science field days" for elementary and middle school students in rural counties of Georgia. As of October 2017, we had worked with over 2150 students at outdoor events held at the Georgia Mountain Research and Education Center near Blairsville and at one of our instrument sites in Lincoln County. Activities are based on hands-on exercises in seismology, plate tectonics, and mineralogy designed for small groups (10-15 students at a time). This work was featured in the EarthScope Newletter (*Grassi, Winter 2017/2018*).

Georgia Mountain Center for Research and Education, site for "science field days". The peak to the left is Coosa Bald, elevation 4271 ft.

Rob Hawman (UGA) with fourth-grade students. Photo by Karen Fischer.

Grant Support at UGA:

National Science Foundation grants EAR-0844154 & EAR-1830182.

Publications

Hanawalt, Laura E., Michael P. Cuilik, and R. B. Hawman, 2024, Using contrasts in horizontal P-wave reflectivity to map the base of the continental lithosphere: Results for the central and eastern U.S., *Tectonophysics, 891*, https://doi.org/10.1016/j.tecto.2024.230512.

Hawman, R. B., 2024. Software and data files for the analysis of P-wave reflectivity of the upper mantle beneath the central and eastern U.S., https://doi.org/10.5061/dryad.z08kprrjq.

Verellen, Devon N., Erik C. Alberts, Gustavo A. Larramendi, E. Horry Parker, Jr., and R. B. Hawman, 2020, P-wave reflectivity of the crust and upper mantle beneath the Southern Appalachians and Atlantic Coastal Plain using global phases, *Geophysical Research Letters, 47,* doi:10.1029/2020GL089648.

Grassi, E., Open SESAME, *EarthScope Newsletter*, Winter 2017/2018.

Parker, E. Horry, R. B. Hawman, Karen M. Fischer, and Lara S. Wagner, 2016, Estimating crustal thickness using *SsPmp* in regions covered by low-velocity sediments: Imaging the Moho beneath the Southeastern Suture of the Appalachian Margin Experiment (SESAME) Array, SE Atlantic Coastal Plain, *Geophysical Research Letters, 43*, doi:10.1002/2016GL070103, published online 13 Sept. 2016.

Parker, E. Horry, R. B. Hawman, Karen M. Fischer, and Lara S. Wagner, 2015, Constraining lithologic variability along the Alleghanian detachment in the southern Appalachians using passive-source seismology, *Geology, 43,* 431-434, doi:10.1130/G36517.1.

Parker, E. Horry, 2014, Crustal magnetism, tectonic inheritance, and continental rifting in the southeastern United States, *GSA Today, 24*, no.4-5, 4-9, doi: 10.1130/GSAT-G192A.1.

Parker, E. Horry, R. B. Hawman, Karen M. Fischer, and Lara S. Wagner, 2013, Crustal evolution across the southern Appalachians: Initial results from the SESAME broadband array, *Geophysical Research Letters, 40, 1-5, doi: 10.1002/grl.50761* (published online 8/6/13).

Selected Abstracts

Hanawalt, L. E., M. P. Cuilik, R. S. Hufstetler, and R. B. Hawman, 2021, Structure of the lithosphere across the Appalachian Orogen: Reflection profiling using earthquakes, Southeastern Section of the Geological Society of America, Annual Meeting, Auburn, AL, April 1, 2021.

Rice, T. A., 2019, The resilience of Appalachian topography: A geophysical analysis of the root structure of the southern Appalachians, CURO Symposium, University of Georgia, April 8, 2019.

Rice, T. A., H. E. Luke, and R. B. Hawman, 2019, Wide-angle reflection mapping and P-wave velocity analysis of the South Georgia Basin and root of the Appalachian Mountains, Southeastern Section of the Geological Society of America, Annual Meeting, Charleston, SC, March 28-29, 2019.

Clements, A. G., G. A. Larramendi, and R. B. Hawman, 2019, Investigating rift basins and underlying crust beneath the southeastern Atlantic coastal plain using teleseismic phases recorded by the SESAME broadband array, Southeastern Section of the Geological Society of America, Annual Meeting, Charleston, SC, March 28-29, 2019.

Parker, E. H., R. B. Hawman, K. M. Fischer, L. S. Wagner, and V. Lekic, 2011, Preliminary results from the Southeastern Suture of the Appalachian Margin Experiment (SESAME): Initial Observations and a comparison between vault and direct-burial stations, *Annual Fall Meeting of the American Geophysical Union,* December 2011, San Francisco.

Wagner, L. S., K. M. Fischer, and R. B. Hawman, 2011, Imaging the ancient margin: updates from the SouthEastern Suture of the Appalachian Margin Experiment; SESAME", *Annual Meeting of the Geological Society of America, Geological Society of America Abstracts with Programs, 43(5), 436,* Minneapolis, October 2011.

Fischer, K. M., L. S. Wagner, D. W. Forsyth, and R.B. Hawman, 2010, Understanding the lithospheric suture between Laurentia and Gondwana: A passive seismic experiment in the southeastern U.S., oral presentation by R. B. Hawman at *Geological Society of America, NE-SE Sections, Annual Meeting, Abstracts with Programs, 42(1),* 99, Baltimore, MD, March 2010.

Wide-Angle Studies of the Crust and Upper Mantle: Southern Appalachians

Looking north across the Blue Ridge Mountains of northeastern Georgia and western North Carolina.

Isostatic Compensation of Mountain Topography

Prior to the SESAME project we conducted a series of wide-angle seismic reflection experiments in the Blue Ridge Mountains, Inner Piedmont, Carolina Terrane, and Coastal Plain of Georgia and

North Carolina to test models for isostatic compensation of topography (*Hawman et al., 2012; Baker and Hawman, 2011; Hawman, 2008; Hawman, 1996*) . We used 5 controlled blasts and over 110 timed quarry blasts as seismic sources; the profiles cross the Appalachian gravity gradient and gravity low and sample the highest elevations within the orogen.

The wide-angle experiments supplement existing COCORP and ADCOH profiles by taking advantage of elevated reflection coefficients near the critical angle. The strategy was to deploy small-aperture arrays of three-component seismometers over a wide range of source-receiver distances (5-200 km) to constrain P-wave and S-wave velocities while keeping receiver spacings small enough (200 meters) to provide unaliased recordings of wide-angle reflections for migration.

Migration of P, SV, and SH reflections suggests that crustal thickness increases from 35 km within the Coastal Plain to over 50 km along the southeastern flank of the Blue Ridge Mountains. Crustal thickness within the Blue Ridge Mountains ranges from 47 to 56 km; receiver functions for two broadband stations in the Carolina Terrane and Blue Ridge show a similar trend. The greatest Moho depths are associated not with the tallest peaks, but rather with the broadest portions of the mountain chain. This observation is consistent with regional bending of the lithosphere. However, the planar basement surface beneath the orogen suggests that the root either predates Alleghanian thrusting, and therefore is unrelated to the present topography, or formed in response to some other mechanism (*Hawman et al., 2012*). The root was further mapped by *Parker et al. (2013)*, who proposed a model involving partial extension of a broad zone of crustal thickening to explain the disparity between the configurations of the Moho and detachment (see previous section on the SESAME experiment).

Grant support at UGA: NSF grants EAR-9105716 & EAR-0124249.

Publications

Hawman, R. B., M. O. Khalifa, and M. S. Baker, 2012, Isostatic compensation for a portion of the southern Appalachians: Evidence from a reconnaissance study using wide-angle, three-component seismic soundings, *Geological Society of America Bulletin, vol. 124, no. 3/4,* 291-317, *doi:10.1130/B30464.1* (published online 10/14/11).

Baker, M. S., and R. B. Hawman, 2011, Crustal structure in the southern Appalachians: A comparison of results obtained from broadband data and three-component, wide-angle P and S reflection data, *Bulletin of the Seismological Society of America, 101,* 2796-2809, *doi: 10.1785/0120100341.*

Hawman, R.B., 1996, Wide-angle, three-component seismic reflection profiling of the crust beneath the East Coast Gravity High, southern Appalachians, using quarry blasts, *J. Geophys. Res., 101*, 13,933-13,945.

Crustal Imaging with Quarry Blasts

Quarry blasts can be very useful as seismic sources because they generate a significant amount of shear-wave energy (*Hawman, 1996*), but the extended source signatures produced by ripple firing can greatly complicate the interpretation of records. A fair amount of effort, therefore, has been devoted to the investigation of various techniques for deconvolving non-minimum-phase signals (*Hawman, 2004*). We've had some success using a combination of minimum-entropy deconvolution with spectral whitening. We have also developed an alternative procedure for migrating common-source gathers (*Hawman, 2004; 2008*). This has been particularly useful for generating single-fold images from data recorded with isolated, short-aperture arrays.

Grant Support at UGA: NSF EAR-9628615 & EAR-0124249.

Publications

Hawman, R. B., 2008, Crustal thickness variations across the Blue Ridge Mountains, southern Appalachians: An alternative procedure for migrating wide-angle reflection data, *Bulletin of the Seismological Society of America, 98,* 469-475.

Hawman, R.B., 2004, Using delay-fired quarry blasts to image the crust: A comparison of methods for deconvolving mixed-delay source wavelets, *Bull. Seism. Soc. Am., 94*, 1476-1491.

Experiments in the Elberton Granite and Eastern Tennessee Seismic Zone

Other recent field experiments include a pilot study using instantaneous blasts at dimension-stone quarries within the Elberton Granite of northeast Georgia (*Khalifa and Hawman, 2005a,b*). The principal goal of this study was to image the base of the intrusion; field gathers for several of the blasts show prominent reflections that migrate to depths between 2-4 km, possibly marking a layered complex at the base of the granite. The migrated sections also show a gently dipping reflection complex at 9.5-11 km that correlates with COCORP images of the master decollement.

We have also conducted pilot studies in the Eastern Tennessee seismic zone, in cooperation with Martin Chapman at Virginia Polytechnic Institute and Christine Powell at the University of North Carolina at Chapel Hill (now at CERI, University of Memphis). Although sparsely sampled, preliminary migrated sections (*Hawman et al., 2001*) suggest the presence of several highly reflective structures, including a concentration of reflectors at a depth of about 25 km, close to the maximum reported depth for earthquakes in the region. The long-term goal of this work is to construct localized models of P and S velocity structure and reflectivity that should help us to better understand the factors responsible for seismicity within this region.

Grant Support at UGA: NSF EAR-9628615.

Publications

Khalifa, M.O., and R.B. Hawman, 2005a, Wide-angle seismic imaging of the Elberton granite, Georgia: A pilot study using instantaneous blasts at dimension-stone quarries, *Geophysics, 70*, B67-B72.

Khalifa, M.O., and R.B. Hawman, 2005b, Speculations regarding the subsurface geometry of the Elberton granite from sparse wide-angle reflection data, *Southeastern Geology, 43*, 193-214.

Hawman, R.B., M.C. Chapman, C.A. Powell, J.E. Clippard, and H.O. Ahmed, 2001, Wide-angle reflection profiling with quarry blasts in the Eastern Tennessee seismic zone, *Seismological Research Letters, 72*, 108-122.

Shallow Profiling with Electrical Resistivity and Seismic Surface Waves

More recently, we completed a series of electrical resistivity profiles over a landslide in southwestern North Carolina and combined resistivity and surface-wave profiles over karst terrain near Albany, Georgia (*Parker & Hawman, 2012; Wylie et al., 2014*). The profiles over the landslide show strong contrasts in the wavelength and amplitude of resistivity anomalies across the edges of the slide. For the surface-wave profiles, we used two different sources (sledgehammer and a moving passenger van) to address the trade-off between lateral resolution and depth penetration of structure. The profiles over karst terrain image the contact between sandy-clay overburden and limestone bedrock, a hidden burn pit within the overburden, and dissolution features with the bedrock itself. The results are constrained by a well and standard penetration tests at three additional borehole sites. A zone of weathered rock at depths of 12-20 meters imaged along a suspected fracture zone is consistent with borehole data and sinkhole formation at the ground surface.

Grant Support at UGA: NSF EAR-9305511.

Publication and Abstracts

Wylie, W., R. Jubran, E. Gallagher, C. Carnes, B. Hundley, T. Nguyen, M. O. Khalifa, P. Schroeder, J. Dowd, and R. Hawman, 2014, Shallow geophysical studies of natural hazards and groundwater systems in the southeastern U.S., Spring 2014 meeting of the Southeastern Section of the Geological Society of America, Blacksburg, Va., April 10-11, 2014.

Parker, E. H., and R. B. Hawman, 2012, Multi-channel analysis of surface waves (MASW) in karst terrain, southwest Georgia: Implications for detecting anomalous features and fracture zones, *Journal of Environmental and Engineering Geophysics, 17*, 129-150.

Parker, E. H., and R. B. Hawman. 2010, Multichannel analysis of seismic surface waves in karst terrains: Implications for detecting subsidence features and bedrock lineaments, *Geological Society of America, NE-SE Sections, Annual Meeting, Abstracts with Programs, 42(1),* 112, Baltimore, MD, March 2010. ***[received award for best graduate student poster, SE Section of GSA]***

Shallow Seismic Reflection Profiling

We have used a 24-channel system for continuous, "roll-along" CMP profiling over several major fault zones within crystalline terrains. Profiles in the Carolina Terrane of northeast Georgia (*Clippard and Hawman, 1995*) were shot over several mafic/ultramafic complexes to determine their subsurface geometry. Profiles (total length: about 1 km) recorded with 100-Hz geophones at 1-m intervals and very light taps with a sledgehammer show strong reflectors close to the time predicted by field mapping, supporting the interpretation of the ultramafics as klippen in thrust-fault contact with surrounding rocks.

Profiles within the Brevard Zone (total length: 1 km) were shot within a few kilometers of ADCOH Lines 1 and 2 in South Carolina (*Hawman et al., 2000*). In spite of strong attenuation and statics effects associated with a zone of severe chemical weathering, the profiles show events that correlate with projections of mapped lithologic contacts.

Coherent reflections have also been observed in shallow profiles recorded over an exposed mylonitic shear zone in the Ruby Mountain metamorphic core complex of northeast Nevada (*Hawman and Ahmed, 1995*).

We have also used the shallow system with a modified shotgun source to obtain profiles across Sapelo Island, a Pleistocene/Holocene barrier island off the coast of Georgia (*Adesida, 1999; Adesida et al., 2000*). Shotgun blanks generated energy sufficient to image features to depths of about 270 m. The CMP stacked sections show several erosional surfaces within Miocene, Oligocene, and Eocene sequences.

Grant Support at UGA: NSF EAR-9117512, EAR-9305511

Publications

Hawman, R.B., C.L. Prosser, and J.E. Clippard, 2000, Shallow reflection profiling over the Brevard Zone, South Carolina, *Geophysics, 65*, 1388-1401.
Clippard, J.E., and R.B. Hawman, 1995, Shallow seismic reflection profiling over an ultramafic complex in the Carolina Terrane, NE Georgia, *South Carolina Geology, 38*, 79-94.
Hawman, R.B., and H.O. Ahmed, 1995, Shallow seismic reflection profiling over a mylonitic shear zone, Ruby Mountains - East Humboldt Range metamorphic core complex, NE Nevada, *Geophys. Res. Lett., 22*, 1545-1548.

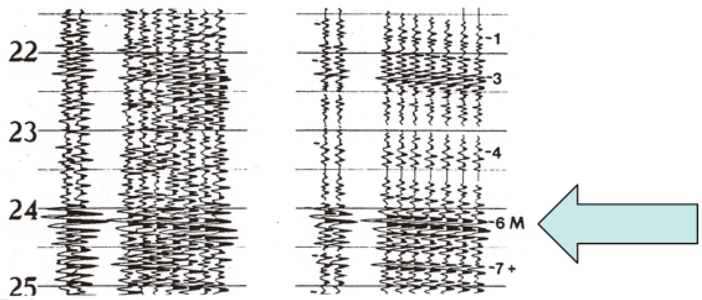
Abstracts

Adesida, Adebola, 1999, The stratigraphic framework of Sapelo Island, Georgia: A Seismic Reflection Study, (abs)., AAPG Foundation grants-in-aid abstracts, *Am. Assoc. Petroleum Geologists Bull., 83,* 1881.
Adesida, A.O., J.E. Clippard, and R.B. Hawman, 2000, the stratigraphic framework of Sapelo Island, Georgia: A shallow seismic reflection study (abs.), *Geol. Soc. Am., SE Section*.

Other Research

We have also conducted wide-angle reflection studies of the crust in the central Appalachians (*Hawman & Phinney, 1991; 1992a, b*), northern Appalachians (*Hennet et al., 1995*), the Great Valley of California (*Colburn & Hawman, 1992*), the Archean gneiss terrane of southern Minnesota (*Gohl et al., 1993*), and the Nevada Basin & Range (*Valasek et al., 1987; Hawman et al., 1990*).

View of Hawk Mountain, along the southeastern flank of the Valley & Ridge in Pennsylvania.



Wide-angle reflections generated by a quarry blast in the central Appalachians, recorded with a short-aperture array (blast duration: 0.25 seconds; distance: about 124 km). Before (left) and after (right) coherency filtering. Migration of event "M" (interpreted as the Moho) suggests a crustal thickness of 44 km beneath the Conestoga Valley of southeastern Pennsylvania (Hawman & Phinney, 1992b).

Publications

Colburn, R.H., and R.B. Hawman, 1992, Inversion of deep crustal refraction data from the Great Valley, California, *Bull. Seism. Soc. Am., 82,* 2224-2247.

Gohl, K., R.B. Hawman, and S.B. Smithson, 1993, Wide-angle reflection studies of the crust and Moho beneath the Archean gneiss terrane of southern Minnesota, *Geophys. Res. Lett., 20,* 619-622.

Hawman, R.B., and R.A. Phinney, 1991, Analysis of sparse wide-angle reflection data in the tau-p domain, *Bull. Seism. Soc. Am., 81,* 202-221.

Hawman, R.B., and R.A. Phinney, 1992a, Structure of the crust beneath the Great Valley and Allegheny Plateau of eastern Pennsylvania, Part 1: Comparison of linear inversion methods for sparse wide-angle reflection data, *J. Geophys. Res., 97,* 371-391.

Hawman, R.B., and R.A. Phinney, 1992b, Structure of the crust beneath the Great Valley and Allegheny Plateau of eastern Pennsylvania, Part 2: Gravity modeling and migration of wide-angle reflection data, *J. Geophys. Res., 97,* 393-415.

Hawman, R.B., R.H. Colburn, D.A. Walker, and S.B. Smithson, 1990, Processing and inversion of refraction and wide-angle reflection data from the 1986 Nevada PASSCAL experiment, *J. Geophys. Res., 95,* 4657-4691.

Hennet, C.G., R.B. Hawman, and R.A. Phinney, 1995, Slant stacks of refraction data from Maine: Effects of lateral variations in velocity structure, *Bull. Seism. Soc. Am., 85,* 1541-1559.

Long, L.T., A. Kocaoglu, R.B. Hawman, and P. Gore, 1994, The Norris Lake earthquake swarm of June through September, 1993: Preliminary findings, *Seism. Res. Lett., 65,* 171-174.

Valasek, P., R.B. Hawman, R.A. Johnson, and S.B. Smithson, 1987, Nature of the lower crust and Moho in NE Nevada from wide-angle reflection measurements, *Geophys. Res. Lett., 14*, 1111-1114.