Here are the unedited comments sent to me from the MSA server-list. Mainly these folks are professors at colleges and universities; some may be professional researchers. Most are Americans but there is a European component.
The line separates successive responses.
These are unedited . please respect privacy .

thanks
fs

Frank,

Well my response would be on the side of take every math course there is (in the applied side). For most students I think through Calc 3 is OK for required math. For those that have some capacity, then I recommend a minor in math:
Calc 1,2,3
Linear Algebra
ODE
PDE
Numerical Methods

For the geophysics students that is an absolute minimum. The students in geophysics are usually taking a double in math: (add to the above list)
Foundations of Modern Math
Modern Algebra
Advanced Calculus 1
Probability or Statistics for Scientists or Engineers
2 electives, preferably in numerical methods

Bryan Tapp
Chairman
The University of Tulsa

Hi Frank,

I am an igneous petrologist - radiogenic isotope geochemist. I taught mineralogy, petrology, etc. at Old Dominion Univ in Norfolk, VA for 8 years (1990 - 1998) before I was terminated. My own math background includes 1 year of basic calculus and 1 year of statistics, along with an abortive attempt to do another semester of "advanced" calculus at the start of grad school (8 years after my last math class), and a geological statistics class in grad school (unfortunately not very useful).

I am acutely aware that I am limited, professionally, by my lack of adequate math background. PDEs were routinely used in the intro geochem course I took from Dick Holland at Harvard, and also in Lasaga's kinetics class I took at Penn State - seems like

thermo should fall in this category as well. Subsequently, in my research, trying to address mixed volatile solubility in magmas and their relation to magma viscosity and flow dynamics, I was stymied. Presently, looking at the sensitivity of Sr isotopic compositions in the global ocean to Sr fluxes from various sources, etc., I am at the limit of my toolbox.

I used Tony Philpotts' book as the text for my petrology class. I loved the unapologetic quantitativeness of the book; compared with Best and other descriptive texts, I think it provided students insight into how to frame petrologic questions in terms of basic principles of physics and chemistry. OK, so doing the integrations and derivatives was hard for me as a teacher, but even harder for my students who, though they took college calculus, apparently didn't learn how to use it. I think that is the crux of the problem: classes in math are fine, but learning to apply them to real situations in geology is tough.

My take on this is - at least one year of calculus, and I agree that another term of intro to PDE and math analysis methods (maybe even finite difference models) is very useful. This needs to be balanced against what the goals of the target audience really are. At ODU, over 50% of our undergraduates (approx 100 students at the time) were studying to be high school earth science teachers. A student population looking to go to grad school in any of the sciences would benefit greatly from the 1 year plus 1 term math requirement. I have been well served by the year of statistics classes I took as an undergrad; understanding the uncertainties of radiogenic isotopic data requires more than just passing acquaintance with error analysis. I certainly think undergrads would benefit from a good stat class. Between math and statistics, this adds up to 2 full years of math. In many institutions, this qualifies as a math minor - and the fallout is that, if you end up going into high school teaching, this would likely qualify you to teach high school algebra.

Good luck with sorting out the conflicting time constraints in the curriculum!

Cheers,
Dr. Francis Ö. Dudás
Laboratory Manager, 54-1117
Earth, Atmospheric and Planetary Sciences
Massachusetts Institute of Technology

The arguments for calculus and differential equations presented all sound good. Unfortunately, if they are enforced, geology enrollments would take a nose dive. Why were the BA degrees in earth science and all the other euphemisms for no math + no chemistry + no physics developed? For those students who cannot do any or all of these topics, and we wonder about the quality of our programs. That is truly a joke.

The suggestion that statistics is not needed also borders on insanity. All you have to do is go to a MS or PhD exam and ask a few questions about the statistics of the data collected

and the meaning of the standard error of the coefficients and their significance and you will be astonished at the answers you get. The most common is, "Those numbers were generated by the statistical package on my computer, and I don't know what they mean." Significant figures and their meaning seems to have disappeared with the Persian empire. These ridiculous 4 or 5 decimal point values reported on data sets that may have 2 or 3 significant figures shows the students and faculty both need some education on this topic.

Just like the sardine factory, we are judged on quantity of production and not quality. The age of social promotion has advanced from elementary school to graduate school, and it may be too late to try and return to classical education where something other than reading and writing are necessary. Arithmetic is just too hard!!
Guerry McClellan
Professor Emeritus

I personally wish that I had taken more math as an undergraduate. Most graduate students don't have the opportunity to take any more math and I personally can see a lot of research projects that I might take on if I had the background.
Karla Kuebler
Earth & Planetary Sciences
Washington University
St. Louis, MO 63130
Well, my institution is currently me :-), but I studied at Caltech, Harvard, and UCLA.

I think a mineralogist needs statistics, at least as far as understanding whether results are meaningful. Enough math to handle complex refractive indices would be good as well. During the 1980s, mineralogy/mineral physics was becoming rather quantum, so at the graduate level applied mathematics as far as Greens functions were useful. I would agree with your request for undergraduate statistics and mathematical analysis.

Hope that helps,
--Mary

From: smiller@alumni.caltech.edu
Hi Frank,

I didn't want to spam the MSA list with my response, but I completed undergrad in 2000 at Wellesley College, which only offers BAs. Our formal requirements for the geology major at the time only involved four course of math or science of any flavor outside the geology department. However, students were informed that grad schools would want at least a year of chem, physics, and math from a geology candidate. This gave students great latitude in choosing as mathematically intensive or nonexistent an undergrad program as we desired.
I can't say how this served others...I took through ODEs in undergrad and

went on to Caltech. I wish I'd taken a statistics course, but I would have appreciated it most if it were a rigorous yet applied course geared toward scientific problems. Tapio Schneider might teach such a thing at Caltech currently. Now I have to read up on my stats instead. I also didn't take linear algebra (a prof told me I could just learn it myself in "a weekend"-ha!). I think linear algebra should be strongly recommended for students...people really do solve problems using it in geochem/petrology and it can be a nifty tool.
Perhaps my recommendation for a BS would be to force people through vector calculus and lean on them to consider stats and linear algebra (and beyond!).
Cheers,
Sarah Miller

Frank: Many years ago, when I was a student at Carleton College in Northfield, Minnesota (Class of 1954) I had 5 semesters of math, 2 of "Freshman Math", 1 each of differential and integral calculus, and a semester of differential equations.During a sabbathical at UCLA I sat in on a course in elementary statistics. For all these years I have been grateful that I took that much math, but nevertheless I have always felt that my math background was a limiting weakness on my scientific work.

So, please try to get as much math as possible for your students.

Best regards and good luck!

M. E. (Pat) Bickford
Syracuse University

From: "Denton S. Ebel" <debel@amnh.org>
To: "Frank J. Spera" <spera@geol.ucsb.edu>

I advise/mentor a lot of undergrads in summers. I would rank statistics over the math analysis item.

Some knowledge of the algorithmic concepts basic to nearly all computer languages: if/then/else, for/next, data types, boolean ops, etc.; and concepts behind image work: bit depth, color fidelity, scaling, are also important to a lot of research. Very few of the kids I encounter know any of this stuff, either.

Subject: Re: Texas Tech ugrad math requirements
X-TechMail-Edge-Route: TTU

Dear Frank

The basic requirement for a Geosciences degree at Texas Tech is Calc I and II (two semesters, totaling 6 credit hours).
For completeness, the Geophysics degree requires the Calc I, II and III and Linear Algebra.
Like the UCSB program, for students majoring or minoring in Geophysics, or interested in the Atmospheric Sciences minor (which is really preparation for the graduate program), we encourage them to take a minor in Maths, or as much additional maths as they can manage. For the minor, in addition to the 4 courses mentioned, two more courses are required, one of which should be Differential Equations. Amongst the other courses suggested are Mathematics for Engineers & Scientists, Mathematical Statistics for Engineers and Scientists and Higher Mathematics for Engineers and Scientists I and II.
As much as the Department would like students to have a statistics course, the issue is that there is no room in the curriculum. The core curriculum, as required by the State, accounts for over 50% of a students 4-year degree. When the minor, plus the core subjects of Geology are added, it is possible for a student to graduate with only 1 elective. Of course, many take additional GEO courses to broaden their horizon, but these are voluntary; as it is, many of the upper division courses are already listed with no credit labs.
Best wishes
Callum

From: Jim Mungall <mungall@geology.utoronto.ca>
To: "Frank J. Spera" <spera@geol.ucsb.edu>
Subject: Re: [MSA-Talk] ugrad math requirements

Hi Frank. It has been a long time, and I hope you are well. Our undergrad requirements at the University of Toronto presently correspond approximately to the additional level you are contemplating, with a full year of freshman calculus as well as a linear algebra course and a second year 'geomath' course or similar introductory statistics course. We raised them, as you are considering doing, a couple of years ago, in a move I pushed for as undergraduate chair at the time. In our case we had little choice, because the practise of geoscience in Canada is now governed by professional bodies like those for engineers (one for each province) and the 'knowledge requirements' for admission to the Association of Professional Geoscientists of Ontario dictated the change. Jim Mungall

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Frank

As it turns out, we are going through this exact same conversation right now. Our current ES degree requires 1 year of Math past College Alg.
That means at least 1 quarter of Diff Calc. The other two quarters are a mix of Calc or Statistics depending on the specific degree option.

Ideally, students should take it all - but of course, any additional Math courses must come at the expense of something else. In our case, we have a required Core of "Baccalaureate core" courses that take up a huge chunk. So - if you add more math - what you are talking about is telling them to take less Chem, Phys or Geo - they already have relatively few real electives (<20 credits in our degree).

Of course, that is what Engineers do - they load up the requirements with Math, and have NO free electives - but that is engineers - can we offend them - since they aren't listening anyway?

So, our real choice is to cut the left arm or the right. Math - core Science - our own basic courses - or the few remaining Electives - that our best students use for research/senior thesis credits?

No good choices - but there are choices - all of them have consequences.
Dr. Roger L. Nielsen
Department of Geosciences
252 Wilkinson Hall
Oregon State University

From: Kirsten Nicolaysen <nicolakp@whitman.edu>
Subject: Re: [MSA-Talk] ugrad math requirements
Date: Mon, 11 Jan 2010 12:21:58 -0800
To: "Frank J. Spera" <spera@geol.ucsb.edu>
Hi Frank,
Our department is divided with one of us thinking that math should be a greater part of the curriculum but rest are more interested in the limited credits being allotted to geology classes. We tend to have two types of majors, most have very good critical thinking skills and are well-above average writers, but who see taking more math classes as a detriment. A minority (10-25%) find writing challenging but are happy to take more math and often do so (through Calc III and Diff Eq, sometimes linear algebra).

We have quite a few "combined" majors. Please keep in mind this is a BA program.
Geology majors are required to take Calc I (one semester) or Statistics.
Geology-Chemistry majors take one year of Calculus (I and II).
Biology-Geology majors are not required to take math though take a year of Chemistry and Physics in addition to most bio and geo classes.
Astro-Geo majors take a year of Calculus and 5 upper level math classes are recommended.
Geo-Physics majors take 6 math classes, which includes all the calculus available plus Diff EQ.
Geo-ES majors take a quantitative credit which includes statistics.

I did not enjoy math until graduate school when I realized how many neat things you can do with it. For me it's about the application to what I love. I was not encouraged to take

enough math (one semester Calc only) during my BA. Happily my MSc advisor recommended beaucoup math. I advise my students to take as much math as they can (though as junior faculty haven't been able to change policy). We would probably agree to add one more math class to the requirement if I would drop the chemistry requirement from one year to one semester. I haven't been willing to do that.
Looking forward to seeing the compiled results, Kirsten

Dear Frank,

We've had a similar discussion recently, only it was about how should an entering grad student be expected to have. Some of our faculty were leaning toward less math than a year of calculus, and one or two wanted some statistics. I don't think we came to any consensus.

1. For our undergrads at Tennessee, we require two semesters of calculus (the variety for science and math majors; we also have a course in business calc).
2. >From my perspective, this amount is just basic math. Today, a lot of students get this in high school. i don't think it's a burdensome requirement. I agree that more math is better, but a lot of students are interested in other aspects of Earth science. At that point I advise students to take courses that prepare them for the field they wish to pursue. For those interested in quantitative geosciences, more math. For those in to bio sciences, stats would be appropriate. And then there are the cognate science courses to consider. So much to learn and so little time!
I'd be interested in the results of your survey.
Best Wishes,
Ted
Dr. Theodore C. Labotka

Frank:
This was a discussion in our Geology Dept here at University of Toronto a few years back. At issue were complaints from students regarding required math courses which were offered by the Math dept, in which students did not feel the examples or course material were relevant to courses taught in the core geology program. We did a couple of things to try and address this, first by including much more quantitative problem solving and treatment of real data in the core courses, and second by adding a course we call "Quantitative Methods in Geology" (see: http://www.geology.utoronto.ca/students/undergraduate-students/course-listing/2nd-year-courses/glg204h1-quantitative-methods-in-geology/ for a syllabus). This seems to have squelched the rumblings. In terms of math requirements, we now have students take a full year of calculus and a half year of linear algebra, with stats recommended. Note also the this amount of math, including stats, is required for registration as a professional geoscientist in most provinces in Canada (ability to achieve this status is required by most Canadian employers now). As a geology undergraduate at McGill I took three semesters of calculus, one of linear algebra, one of ordinary differential equations, one of numerical methods and one programming course. I must admit that the geology courses I took as an

undergrad did not use much of that math, but I found the background incredibly useful, especially in courses related to kinetics and thermodynamics.

best regards,
James Brenan
Department of Geology
University of Toronto

Hello Frank,

A quick response to the first question of your courriel. Here in Québec the system is a little different from that in the U.S. Two years of CEGEP (= junior college in the U.S.) cap five years of secondary (= high in the U.S.) school and precede the three years of university required for the undergraduate degree ("Premier Cycle"). For a baccalauréat (= a U.S. undergraduate degree) in geology, in CEGEP students must take a semester of differential and a semester integral calculus and a semester of analytic geometry. Statistics is optional. At university these students are obliged to take a semester of intermediate (advanced?) calculus which builds on that learned in CEGEP. A few, particularly those in engineering geology and hydrology, take more advanced optional math courses.

I am not prepared to reply to the second question. It carries too many variables.

I hope that this helps.

All the best,

Tomas.

Hi Frank,

In response to your questions -

1. what is the actual requirement in math for UNDERGRADUATE degrees
in EARTH SCIENCE (sensu lato) at your institution???

We require one year of calculus plus one additional math course. This is usually statistics. We consider this to be a minimal requirement.

2. More generally, as a working earth scientist how much math do YOU
think SHOULD be required for an earth science undergrad?
How much statistics? Is linear algebra impt. ? Is elementary math
of complex systems (non linear ODE's) impt. enough to be required of
all? Giving some detail regarding the "level" would be helpful.

As an undergraduate I took a year of calculus and since then I've had no further formal course work in mathematics. I find that I virtually never use calculus. This may be more an indictment of my level of math sophistication than what is actually needed. The one area in which I often find myself deficient, and for which I seek help from others, is statistics. For the type of work I do in igneous petrology and geochemistry statistical analysis is the greatest need.

To comment further on this whole issue of mathematics, I find students entering my institution to be totally unprepared in algebra and trigonometry. Students don't know how to solve simple equations and trigonometry, which is very basic to certain topics in crystal chemistry, mineralogy, and structural geology, is essentially unknown to them. Perhaps we should worry more about these basic mathematics skills.

Most of our students enter the job market after they get their bachelors degree. Universally they seem to have no need for calculus. For the students who go on to get MS degrees in geology, once again the major need seems to be algebra and trigonometry.

I am, of course, answering these questions from the perspective of someone who teaches at a state university. It will be interesting to see what my colleagues at the "elite"schools have to say about mathematics.

Cheers,
Nelson Eby

Nelson Eby
co-Editor-in-Chief *Lithos*
Department of Environmental, Earth, & Atmospheric Sciences
University of Massachusetts

From: Glenn Waychunas <gawaychunas@lbl.gov>
To: "Frank J. Spera" <spera@geol.ucsb.edu>
Subject: Re: [MSA-Talk] ugrad math requirements

Hi Frank:
I think that geosciences are such a diverse field that one could get by reasonably with one year of math in many cases if it includes linear algebra and things like fundamental analysis. You could pick up the statistics from papers and books as needed, and many do. Years ago when I was at UCLA as a grad student, many new grads added to their math background with courses in applied math as needed.
This possibility affects what might be offered. A student heading to grad school could pick up more math as they advance, while a geologist with only a BA may not have access to remedial and additional course offerings, and hence may need that additional background in statistics, etc.
However besides the specific work that we do, we also have to comprehend the journal articles. I cannot speak for all geochemistry, but for mineralogical spectroscopists like

myself, I rely on my second year of math skills from time to time and frequently for papers I read, often in the physics literature. Students may also need more than first year math for P-Chem, which is important for mineralogy, spectroscopy, advanced x-ray techniques, etc.
I had differential equations courses (as I started as a math major long ago), but I don't work on analytic solutions to nearly anything, and instead resort to approximate computer techniques that pull all the weight. It does worry me from time to time that I don't fully comprehend what's in the codes I use, but I can call on specialists to bail me out if I know enough to ask decent questions. A good founding in math does help you with formulating such "decent questions".
Perhaps someone will comment on current math requirements at UCLA, Berkeley and Stanford.
Glenn Waychunas
Berkeley

From: Charles Trupe <chtrupe@GeorgiaSouthern.edu>
Subject: Math requirements

Frank:
Pranoti Asher forwarded me your email about math requirements for an undergrad geology degree. I chair our department's curriculum committee here so I thought I'd pass our info along. So, in response to your questions:

1. what is the actual requirement in math for UNDERGRADUATE degrees in EARTH SCIENCE (sensu lato) at your institution???

We require either two semesters of calculus or Calc I and statistics for the BS geology degree. We also have a geology BA that only requires pre-calculus or trig.
2. More generally, as a working earth scientist how much math do YOU think SHOULD be required for an earth science undergrad? How much statistics? Is linear algebra impt. ? Is elementary math of complex systems (non linear ODE's) impt. enough to be required of all? Giving some detail regarding the "level" would be helpful.

I feel that Calc I and II plus a basic introductory statistics course should be the minimum for a BS personally. When I got to grad school, I had two calculuses and one statistics course as an undergrad. My advisor recommended that I take a third semester of calculus, linear algebra, and differential equations. I was doing structural geology and metamorphic petrology so the math helped, and the graduate-level physical geochemistry course I took in my first semester really helped me apply the math and understand it better. I advised an undergrad here who passed Calc I and kept dropping Calc II. She was working on palynology research and her research advisor thought statistics would be more useful to her than the second semester of calculus, so that's what she did. I typically advise my students who plan to go to grad school to take as much math as they can, but at the very least two semesters of calculus. More math can't hurt.
Regards,

Dr. Charles H. Trupe
Associate Professor of Geology
Georgia Southern University

From: Gordon Moore <gordon.moore@asu.edu
To: "Frank J. Spera" <spera@geol.ucsb.edu>
Hi Frank,
Sorry we missed you at AGU. We had a great dinner w/ Ian over in Berkeley. He seems to be doing amazingly well!

Anyway, here are my $0.02 regarding your question about math requirements . . .

I was an ASU undergrad, and to my knowledge, the requirements haven't changed since then. They were 1 yr calculus (i.e. 2 semesters), plus either 3rd semester calc or linear algebra. That's it. Of course, if you were fortunate enough to get attached to a faculty's research group as I was (John Holloway's), then you got the "secret advisement", which was similar to your advice, "take as much math as you can stand, plus P-chem". So, I ended up at Berkeley as a grad w/ 1 yr calculus, 1 semester Diff Eq, 1 semester, PDE, and 1 semester of Linear algebra.

But, that wasn't enough. Or, maybe it's better to say it was too much of the wrong thing. First, I believe now that statistics is far more important for what I do than understanding Green's functions, etc. Second, I have also come to believe that math for scientists (especially geologists) should NOT be taught in the math dept. After taking Lane Johnson's applied math for geophysics at Berkeley, I am a true convert to applied math classes taught within departments other than the math dept. Unfortunately, most math prof's do not take the time to make the link between a students chosen major/field and the math they are teaching. I know Don Snyder would disagree w/ me, but since most of us are mere math mortals unlike him, the purity of mathematics is not something we appreciate or care about much. We just want to know how to use it and why it's useful. Losing that connection between the application and the math can really suck the motivation out of students, particularly at the undergrad level.

So, here are the enumerated answers to your questions:

1.) 3 semesters, including 1 yr of calculus

2.) 2 yrs minimum, but including at least 1 sem of statistical analysis. As far as the "level", I would require 1 yr calc, 1 sem statistical analysis, and then let them choose between ODE or linear algebra. I would then make undergrads aware of the "other" classes, and/or teach an upper division applied math class.
Hope this helps,
Gordon Moore, Ph.D.
Co-director, Omni Pressure Laboratory
Dept. of Chemistry and Biochemistry
Arizona State University

Hi Frank,

I agree that geo majors need more math, but they need more chemistry too. It's the age old problem of being honest about what students really need and having so many requirements that no one wants to major in geo **VS** sticking with traditional requirements and getting larger numbers of majors but relatively few who are quantitatively capable. This in turn feeds into having an image that geology is somehow less than true science, at least in the eyes of some. Still, geo depts must have majors if they are to survive. It seems to me that chemistry departments are places where one would find the students who are best prepared to do modern mineralogy and petrology, but I have no idea on how to attract such students.

One more thing - maybe the paleo students in your dept need statistics more than they need calculus???

Sorry for the rambling.

Best wishes,

GUY L. HOVIS, Ph.D., John H. Markle Professor
Department of Geology and Environmental Geosciences
Lafayette College,

From: carrick <carrick@uwyo.edu>
Subject: Re: [MSA-Talk] ugrad math requirements
Date: Mon, 11 Jan 2010 14:39:22 -0700

Frank:
Thanks for asking - it's a question we've grappled with for years. On the one hand, yes, the requirements for quantitative thinking are on the increase in Earth Science majors, but on the other hand it seems that undergraduate students are less and less well prepared to engage in any kind of quantitative thinking or problem solving. That said, we've also had the complaint that "I took all these math courses, but most of that math wasn't used in my geology classes". In addition, some of our faculty have had connections in, or taught in, math courses and we had a general perception that there was a decrease in what was covered in the math courses. So, it's a chicken and egg problem; if the major courses don't use certain mathematics because students don't have the background, then when they do have the background you have to bring the major courses up to that standard or it will all seem pointless to the students.

In our major, students pass through two 2000-level courses, one in Geochemical Cycles and the Earth System, and another in Introductory

Geophysics (yes, all undergraduates get an introduction to geophysics...).
Both courses attempt to ramp up
quantitative problem solving so that students can't say "but we didn't
use that math in the course", and we have made an effort to have all
faculty emphasize quantitative approaches in the more advanced courses
throughout the major. We didn't, on balance, think that more courses
in the math department would solve the problem, but that instead the
problem lay in bringing our major content up to the standard we expect
with regard to mathematics - so that the mathematics was integrated
with the major rather than an abstraction separate from the major.

1. what is the actual requirement in math for UNDERGRADUATE degrees
in EARTH SCIENCE (sensu lato) at your institution???

Two semesters - calc I and II.

2. More generally, as a working earth scientist how much math do YOU
think SHOULD be required for an earth science undergrad?
How much statistics? Is linear algebra impt. ? Is elementary math
of complex systems (non linear ODE's) impt. enough to be required of
all? Giving some detail regarding the "level" would be helpful.

We've taken the approach that if the course needs it, you teach the math
that is needed in your course. That way you know that you've covered
what is needed at the right time!

On balance, I would go with statistics before others.
Hope that makes sense-
Carrick

From: jerrym <jerrym@warnercnr.colostate.edu>
To: "Frank J. Spera" <spera@geol.ucsb.edu>
Subject: ugrad math requirements
Frank:
We require three one-credit courses:
MATH 124 01(1-0-0). Logarithmic and Exponential Function. (GT-MA1, AUCC
1B). F, S, SS. Prerequisite: MATH 118 or placement.
Definition and graphs of exponential and logarithmic functions, properties
of logarithmic functions, exponential and logarithmic equations,
applications.
MATH 125 01(1-0-0). Numerical Trigonometry. (GT-MA1, AUCC 1B). F, S, SS.
Prerequisite: MATH 118 or placement.
Definition and graphs of trigonometric functions, laws of sines and
cosines, solutions of right and oblique triangles, applications.
MATH 126 01(1-0-0). Analytic Trigonometry. (GT-MA1, AUCC 1B). F, S, SS.
Prerequisite: MATH 125 or placement.

Inverse trigonometric functions, trigonometric identities, solving trigonometric equations.

College algebra (2 credits) is required by AP credits, or they can test out of it. If they can't do either, they have to take the two one-credit math modules in order to get started in M124.

The main thing that is interesting about these three (M124-126) is that recently I looked carefully at our students and how they did in these courses relative to completing the degree. There was a near 100% correlation between those who easily passed M126 and those who completed the degree. Those who failed, withdrew, or otherwise struggled with M126 almost never completed the degree.

Then they need either a two semester, 8 semester credit calculus sequence:

MATH 155 04(4-0-0). Calculus for Biological Scientists I. (GT-MA1, AUCC 1B). F, S, SS. Prerequisite: MATH 124; MATH 125. Limits, continuity, differentiation, and integration of elementary functions with applications in the biosciences. Programmable graphing calculator required.
MATH 255 04(4-0-0). Calculus for Biological Scientists II. (GT-MA1, AUCC 1B). F, S. Prerequisite: Concurrent registration in MATH 126; MATH 155. Derivatives and integrals of functions of several variables, differential and difference equations, matrices, applications in the biosciences. Programmable graphing calculator required.

Or a three semester sequence (which we encourage):
MATH 160 04(3-2-0). Calculus for Physical Scientists I. (GT-MA1, AUCC 1B). F, S, SS. Prerequisite: MATH 124 or concurrent registration; MATH 126. Limits, continuity, differentiation, and integration of elementary functions with applications; conic sections.
MATH 161 04(3-2-0). Calculus for Physical Scientists II. (GT-MA1, AUCC 1B). F, S, SS. Prerequisite: MATH 124; MATH 160. Transcendental functions, integration techniques, polar coordinates, sequences and series, with mathematical software.
MATH 261 04(4-0-0). Calculus for Physical Scientists III. F, S, SS. Prerequisite: MATH 161. Vector functions, partial differentiation, cylindrical and spherical coordinates, multiple integrals, line integrals, Green's theorem.

You're right, geophysicists want/need more; we're setting up a geophysics concentration and I think they've added at least three more math courses.

Yes, we require a basic statistics course (3 cr), and I strongly agree with adding that. I had one as an undergraduate, it was very influential on me, I had a statistician on my Ph.D. committee, and now I teach a graduate

level Geostatistics course. I think statistics can potentially teach students a lot about how to think about scientific problems, and how to evaluate whether or not they've actually demonstrated anything.

Your Math Analysis course sounds like a good one, and we kicked around the idea of offering our own similar course, in response to the feeling that our students' math skill were weak, and that they are a lot of math tools that they weren't getting exposed to.

So it sounds like a good idea to me. If you were proposing adding another semester of calculus plus, say, differential equations, I'd say you'd be driving off potential majors, and some of your majors wouldn't survive the math (we've seen both effects in our college). But it doesn't sound like these two courses would be overly intimidating to potential students. So adding statistics and a little more math—good idea, but I'm sure you've thought about the trade-offs. What are you going to cut out?

Our students are made up of, I think, three basic groups. 1) Those that want a degree, but will likely never use it, 2) those that will use the degree, but probably not go on for advanced degrees, and 3) the "really good" students who will go on for advanced degrees and perhaps even become academics. When manipulating the curriculum, I think of which groups will be helped and which will be hurt. If one makes the degree harder, you hurt/drive off group 1. If you can afford to do that, fine. But a lot of institutions can't afford to drive off majors.
Just my 2 cents.
Jerry Magloughlin

From: "Peter J. Heaney" <pjheaney@psu.edu>
Subject: Re: [MSA-Talk] ugrad math requirements
X-Originating-IP: 128.118.174.164

Hi Frank,

In answer to your first question, at Penn State we require two 4-credit courses in the basics of calculus for our Geosciences BS majors. These courses are described below:

MATH 140 (GQ) Calculus With Analytic Geometry I (4) Functions, limits; analytic geometry; derivatives, differentials, applications; integrals, applications.
MATH 141 (GQ) Calculus with Analytic Geometry II (4) Derivatives, integrals, applications; sequences and series; analytic geometry; polar coordinates.

Our department offers options in geophysics and hydrogeology. As you suggest, the students in these options must take additional math courses.

In answer to your second question, if Penn State required math beyond basic calculus, we would lose 50% of our majors. (That is a guess, but it is probably reasonable.) So even if I believed that all of our students needed more math (and I'm not sure that I do -- many of our students go into mining or oil or environmental consulting), it would be logistically impossible to implement.

Hope things are sunny at UCSB.

Best wishes,
Peter Heaney

Frank
OSU...BS in Geology. We require 2 quarters of Calculus (Differential, Integral, 4 cr each: a long-term requirement).... some talk of adding in the future a course on Statistics. Our hydrogeologist & CE profs would like more advanced Math, as you note below.

An issue is that we have cut back on upper division geology course requirements (in petrology, petrography, sedimentation, paleontology) and added lower division courses so we are reluctant to add more requirements that will mean further cuts in geology basics. Admission to grad programs these days is a tough business because so few USA BS grads have adequate background in Math-Phys-Chem (or acceptable grades) and much beyond introductory level geology courses.

My 2 cents... Roy may wish to add what he thinks would good for the hydrophiles.

John Dilles
Professor of Geology
Department of Geosciences
Oregon State University

Frank, Here at Stony Brook we have a formal requirement of only two semesters of regular calculus, but students interested in geophysics or quantitative projects often take linear algebra, calculus III and perhaps IV. Since so many do research, they often decide upon this based on the research they are doing. We strive to be as flexible as possible in allowing students to shape the major based on their interest and future goals. The math needs of our students clearly vary. Students going to work in environmental firms straight from college rarely take more math than that required and often struggle just in the basic calculus courses, while those planning on graduate study in a quantitative field take more. Since the the undergraduate committee meets with each major at the end of each semester, we determine what additional math each student needs and when. We have found over the years that flexibility is what makes our students achieve their career goals not rigid requirements.Just a perspective from a large state university dealing with very diverse capabilities of students... Hanna Nekvasil

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Hi Frank,

All great issues and questions. Here is what we do at Texas Tech.

1. As with UCSB, we ask geophysics students to take at least 5 semesters of higher math, starting with Calc I.
2. Geology majors (BS) are required to take Calc I and II.
3. For students with strong interests in geochemistry or petrology, we try to push them into more math, generally with limited success. We would like to see them take Calc III plus a class available here called "Higher Math for Scientists & Engineers", which is essentially differential calculus.
4. Students with interests in paleontology are strongly advised to take statistics at the junior/senior level; also rarely successful.
It is probable that if we raised the math requirements we would lose about 25% of the undergraduate class.
Even if we decided to increase math requirements, we could not because of the front-loaded core curriculum. Our BS program has a mere 3 hours of electives.

Hope this helps,
Cal

Calvin G. Barnes
Professor and Chair
Texas Tech University

Frank

1. what is the actual requirement in math for UNDERGRADUATE degrees in EARTH SCIENCE (sensu lato) at your institution???

At UCDavis our B.S. degrees require a minimum of one year of calculus; some tracks require two years of math; some require a course in statistics in addition to the year of calculus. We may be faced with eliminating the statistics requirement in order to keep a one-year requirement in physics, because the number of units in the physics courses has been increased. That would be a shame, because all scientists should be well-grounded in understanding the quality of data and ways to test hypotheses.

2. More generally, as a working earth scientist how much math do YOU think SHOULD be required for an earth science undergrad?
How much statistics? Is linear algebra impt. ? Is elementary math of complex systems (non linear ODE's) impt. enough to be required of all? Giving some detail regarding the "level" would be helpful.

This is the wrong set of questions. More important is: What would you eliminate from the currently full curriculum in order to provide more training in mathematics? Will you cut other ancillary sciences? Will you cut the earth science topics in the major? Will you make the major more specialized in an era in which breadth of training is increasingly important? It may be that we need to find more efficient ways to present integrated introductory sciences or integrated introduction to mathematics. But in general, I think it

is unreasonable to expect undergraduates to spend more than a year acquiring introductory skills in each discipline ancillary to their major field of study. That said, I can't think of any course work that is more enabling in the long term than math.

Howard

Frank-

Currently we require students to take 2 semesters of calculus (1 year) and another semester of statistics. Ideally, I would like to require another "mathematical analysis" class of the sort you suggest, but we have had difficulty increasing the number of credit hours required by our major. We also require a year of physics, a year of chemistry, and a semester of biology.
I'd like to see the results. Thanks for compiling it.
Eric H. Christiansen
Department of Geological Sciences
Brigham Young University

Frank,
Needless to say, your request is not the least bit annoying .

1. At the university of Idaho we require two semesters of math. A decade or so ago that used to be two semesters of calculus. I successfully argued that we should allow the students to substitute a statistics or linear algebra for one of the calculus courses.

2. If I had my way I'd allow the students to talk two semesters of math, but not require any calculus. I never use calculus, but I use statistics almost daily and linear weekly. BTW: I have a minor in math

I hope this helps,
Mickey Gunter, Professor & Chair
University of Idaho

Here at ONU we have long required a year of Calc and a semester of Stats for the Geology (BS) degree. I think that is entirely appropriate.

Interested to see what kinds of responses you get.
Best,
Charles W. Carrigan, Ph.D.
Assistant Professor of Geology
Olivet Nazarene Univ., Dept. of Physical Sciences

Hi Frank,
We have a math requirement similar to yours - up to elementary calculus. This does not stop a lot of blank looks when I derive the equation for radioactive decay. Undoubtably

more calculus, matrix algebra etc would be good, but I am not sure if it is necessary, and rightly or wrongly would probably impact our majors.

What i do see a huge need for though is a class in statistics. Our students do not know the most basic statistical concepts such as the simple properties of the normal distribution etc. and do not understand very well the concepts of uncertainties in numbers. To me that is a very large part of understand the quantitative aspects of the earth sciences, and will only become more so as it is more data intensive. I try to teach them a little of this and more at grad level, even there I find students who do not really know what a mean and standard deviation are even though they readily calculate them using Excel. A class that uses the earth sciences for examples of teaching statistics would be great.

My 0.1 kroner (see below). I've also cced John Dilles on this as he reads the MSA list and may have other comments.
Adam Kent
Associate Professor
Department of Geosciences
Oregon State University

Hi Frank,

I remember that we talked about this very subject some years ago at an AGU meeting; clearly you have been thinking about this for quite some time.

Here are the math requirements for a B.Sc. Major in our department at McGill (the first two courses are taken by Quebec students at CEGEP {Junior College in Quebec, equivalent to grades 12 and 13} or in the 1st year at McGill for non-Quebec students):

MATH 140 - Calculus 1. Review of functions and graphs. Limits, continuity, derivative. Differentiation of elementary functions. Antidifferentiation. Applications.
MATH 141 - Calculus 2. The definite integral. Techniques of integration. Applications. Introduction to sequences and series.
MATH 222 - Calculus 3. Taylor series, Taylor's theorem in one and several variables. Review of vector geometry. Partial differentiation, directional derivative. Extreme of functions of 2 or 3 variables. Parametric curves and arc length. Polar and spherical coordinates. Multiple integrals.

Also note that "Students who have not had the following course or its equivalent in CEGEP or the Freshman Program may be required to take MATH 133 Vectors, Matrices and Geometry."

Additionally, our students are encouraged take a statistics course (many

are offered by different departments at McGill) such as:

MATH 203 - Principles of Statistics 1. Examples of statistical data and the use of graphical means to summarize the data. Basic distributions arising in the natural and behavioural sciences. The logical meaning of a test of significance and a confidence interval. Tests of significance and confidence intervals in the one and two sample setting (means, variances and proportions). No calculus prerequisites.

Our B.Sc. honours program in Earth Sciences has the same math requirements, but our B.Sc. honours program in Planetary Science (which replaced our Geophysics program about 15 years ago) requires additional courses in Linear Algebra (Math 223), Advanced Calculus (MATH 314), ODE (Math 315), Numerical Analysis (Math 317) and PDE (Math 319).

My personal viewpoint, based upon my career, is that students should be introduced to ordinary and partial differential equations at the bachelor's level and don't need a specialized course in statistics (although they need a basic knowledge of statistics). However to take a course in PDE's at McGill requires 3 pre-requisite courses after Math 222: Algebra 2, Advanced Calculus, ODE. These upper level courses are directed toward majors in math and physics so the level is very high for our students (who in general are math-phobic) and the additional course load is too much for the students to take (who must follow a curriculum approved by the professional "order" to be geologists in Quebec).

Our department is involved in suite of interdisciplinary programs (you can check out the website to see them: www.eps.mcgill.ca . These programs have fewer math requirements than our B.Sc. majors program.

In the ideal undergraduate program that I envision (and tried to institute when I was director of undergraduate studies in my department) students would take a specialized course that would at least teach them the basics of statistics, numerical analysis, ODE and PDE. I think some of this can be done, and will attempt it when I return from sabbatical, in a Geochemical Modelling course that will be inspired by F. Albarede's geochemistry textbook, Tony Lasaga's kinetics textbook, and W.(?) Strogatz's non-linear dynamics textbook.

I hope this information helps you. I will be very interested to see the results of your research on this topic (after all, I am always interested in your research).

Happy New Year from Italy,

Don

Hi Frank, and all,

My personal experience may be enlightening. When I was an undergrad (Earlham College, ,'74) I took a full year of calculus, more than any of my undergrad colleagues. Upon admission to grad school (Northwestern), I was deficient in formal math training (in my department's view), and took two more years of math, including diff. eq., probability and statistics, and applied PDEs. This was basically the same requirement for everyone, including Bob Speed's field guys, out doing structural petrology in Nevada. I ended up as an experimental petrologist, and used both the statistics (to understand the data analysis from my experiments), and the PDEs, to have a basic understanding of the thermodynamics behind my work. My own life would have been much simpler had I been exposed to the statistics of data analysis, and to diff. eq., before I tried to fight my way through P. Chem.

For anyone who is going on to grad school, I'd think that an additional year of math would be a great benefit, with the added provision that their undergraduate geology curriculum should genuinely incorporate the application of math methods to geological problems. As an extreme example, several grad school colleagues and I were simultaneously taking our applied PDE course and a basic geophysics course taught by Norm Sleep. Curiously, throughout the semester, we would learn a technique (like Fourier series solutions to PDEs) one week, and be applying it in geophysics (say, to heat flow) the very next week. Lo and behold! Our applied math prof was acting in collusion with Norm, arranging the order of topics in our math class (within reason) to support Norm's curriculum. To me and my geophysics classmates, both classes made a hell of a lot more sense as a result.

Bottom line; most of us aren't mathematicians, but if we learn early and often that math is a useful tool for us simple-minded geologists, I think we benefit as scientists overall. And when it comes to mathematical skills, the bigger our toolbox, the better.
Cheers,
Jerry

At UNC-Asheville,

1) We only require two maths -- at minimum Precalculus and Statistics, but we recommend strongly a year of calculus for our geology-leaning majors.

2) I think a year of calculus is minimum. Statistics and LInear Algebra (and differential equations) are nice, but you have to squeeze them in with all the other requirements. Thus, we try to get students to take Stat as an elective. We suggest they get differential equations in grad school, particularly if they are going toward hydro careers.

Hope that helps.

Bill Miller

Frank,

At Pomona College, we currently require 2 semesters of Calculus for the BA in Geology. The College also has a separate requirement that essentially ensures that our students get a statistics course under their belt (though there are other ways to fulfill the requirement, so it's not 100%). That's what we require.

Whenever I sit down with a student, I encourage them to get as much math under their belt as possible, ideally through DifEQs -- which unfortunately requires completion of 3 semesters of Calculus plus Linear Algebra. I say 'unfortunately' because this means, in order to require DiFEQs for our students, we'd have to require 5 math courses; with an absolute upper limit of 16 course slots for a major, and a practical limit of 13 (if you want folks to major in Geo since they often start late) there's simply no way to do this. I would *love* to have a course like your 'Math Analysis' on the books for our students here to take; if we did, I think we'd work hard to integrate it into our requirements (directly, or as an elective, or...).

I'd be very curious to see the compilation you put together; we have a dept review occurring in a year or so, and I'm confident these data would be useful to have in hand.

With my regards,

Eric Grosfils, Chair
Geology Department, Pomona College

Hi Frank.

The Chairman and I chatted re: your question, after which he copied me this e-mail.....see below.....it applying to straight GEO majors and those GEO majors with our Geophysics Option and/or Petroleum Engineering minor

To which I will add....in our B.S. Environmental Option the kids take Calc I and II, plus an intro Statistics class; the Calc is needed for Physics, among other things

And.....if pursuing the B.A. option in Geology, they take pre-Calc and Calc-I, plus the Intro Stat

Winton

-----Original Message-----
From: Tapp, Bryan [mailto:jbt@utulsa.edu]
Sent: Monday, January 11, 2010 7:32 PM

To: Cornell, Winton
Subject: RE: [MSA-Talk] ugrad math requirements

From: Jen Chambers <jenchambers@boisestate.edu>
Subject: Re: [MSA-Talk] ugrad math requirements
Dear Frank
I'd be interested in seeing a compilation/summary of the responses you get.
I have little to comment on as I was a UK undergrad and postgrad, so the system/schedule of teaching is different to that in the US. Wish I had had more math classes as an undergrad however - would have made things easier now, but then again, too much may have put me off geology. I think the problem was that when math was taught (for me this includes pre-undergrad days) it was too abstract - if taught with real and important geological data then I think the value of learning it would be evident.
Thanks in advance ,Jen Chambers

Hello:

Steve Kissin at Lakehead University. Meeting the requirements for professional registration in Ontario requires only 1 term of calculus and 1 term of statistics (term= semster). At LU the introductory calculus course is 2 terms as is the introductory statistics. It should be noted, however, that introductory calculus has high school prerequisites and satistics has a prerequisite of calculus.

In my own case, I took only introductory calculus, but it seems to me that it is more rigourous than introductory calculus that students receive now. As a graduate student I took an upper division course in matrix algebra. I never used this and cannot remember anything about it even though I obtained a good grade.

If a studtent is planning on graduate work in crystallography or geochemistry, some more advanced math courses would be useful.
Seteve Kissin

Hello everyone,

To answer Frank's questions:

1. At the University of Vermont we require a year of calculus (very similar topics that you listed) for both the BA and BS degrees, and until recently required a basic statistics class for both, now just the BS requires students to take the stats class.

2. As a geochemist I see value in not only the mathematics classes through PDEs and stats, but also in linear algebra (thermodynamic modeling programs function via construction of matrices for example). A point with any of this discussion is the reality that we cannot require as many classes for undergrads as we would like, there are limits

on credit hours in a discipline a student can take as part of their degree - we bump into this frequently and is the reason the stats class for the BA students was dropped (and a change from two to only one semester of physics required) . I am sure this audience is highly sympathetic to this phenomena with the changes in mineralogy teaching and the dearth of specific optical mineralogy classes taught at universities as we broaden and restructure our curricula. In that light I would prioritize 1 year of calculus, one semester of stats, and then I think you start to want to tailor the curricula a bit for the student (a geochemistry student should be in P-chem and Analytical chem for example, then maybe a linear algebra course).

It is a tough set of choices however, and in mathematics as well as other ancillary courses and geology subdisciplines one has to also ask what the knowledge base for all geology grads should be... a topic for another time however.

Good luck everyone!!

Greg Druschel

Hi Frank,

First, some info on math:
Our dept offers three different degrees - BS in geology, BS in environmental science, BA in geology. Most students get one of the first two degrees -- the BA is rarely used, but works well for folks who want to supplement an education degree with more science as well as the occasional student interested in science journalism or law. It's possible to get a BA with very little math. I'll focus here on the two BS degrees. (You can find info on all of the requirements
here: <http://epswww.unm.edu/ugrad/index.htm>http://epswww.unm.edu/ugrad/index.htm). Currently, we have about 15 students a year coming through the geo BS program, and >25 in the environmental track. All UNM students have to have a minor as well as a major, and our majors generally get a "distributed minor" by combining their required calculus, calc-based physics, and chem classes with 2-3 additional classes from those three depts and/or biology.

Currently, both BS degrees require one year of traditional calculus, plus either a semester of statistics through the math dept or a semester-long "statistics and data analysis" course taught in our dept. Everyone is encouraged to take the latter, which covers about twice as much material as the math class. Our stats course focuses on real data sets from earth and atmospheric sciences, and students have a choice between two sections of the course: one that includes tutorials in use of Excel for solving all of the problem sets, and another which uses MatLab. (Grad students in the course have to take the MatLab version, but undergrads get to choose). In addition to the usual basic statistics, the class covers time series analysis, Fourier analysis, some matrix algebra, etc.

Starting next year, students will have a choice between our data analysis course and another course taught in the dept on mathematical methods in the earth sciences -- this

course includes elements of linear algebra, differential equations, numerical methods, etc. Our dept also offers a course on mathematical modeling approaches in the earth sciences. Amazingly, both of these departmental math classes have been fully subscribed in the last year or two.

You can see from the above that the dept has sort of given up on requiring lots of courses through the math dept in favor of offering our own classes that are tailored to geoscience-related problems. Many of the math dept classes are extremely poorly taught, and our students often end up having to take them multiple times in order to get grades above a C, which they need in order to get credit. The four faculty in our dept who teach the math-related courses are all great teachers (Joe Galewsky, Mousumi Roy, Dave Gutzler, and Peter Fawcett), and they go out of their way to show how the math is used by geo- and atmospheric scientists.

What do I think is the appropriate amount of math for an undergrad major? I'm actually pretty happy with our requirements: one year of calculus, plus at least one course in stats and data analysis and/or one semester that includes some exposure to linear algebra and differential equations. Beyond that, I think it comes down to good advising for each individual student, plus professors in geo classes emphasizing quantitative material and why it is useful to have more math. At the grad level, I encourage my MS students and require my PhD students to take linear algebra and diffEQ.

We have found in the last few years that many of our "top" grad applicants, who come from places like Amherst, Smith, Carleton, etc., have only had one semester each of calculus, chem, and physics, and no statistics. We make all of these folks make up the missing classes, which is a pain for all involved. I wish that there were a little more consistency around the country regarding these background courses.

Folks,

Part of the answer to the question about the appropriate level of training (mastery) in mathematics in the geoscience curriculum obviously lies in the cognate courses that are required. As with many of the former answers, our department requires a year of calculus for all majors, a second year of differential equations for students in our hydrogeology option, and a course in general statistics. I also recommend that students take linear or matrix algebra if they have room in their schedules given the number of applications of these approaches across the geosciences (can't require this due to institutional caps on credit hours allowed, but still, can be handled informally through advising if students' schedules permit). This level of course work seems to be the norm, based on the replies to this listserv.

In addition, perhaps we should also be looking closer to home and try to build quantitative skills in our own courses and curricula. Like training for an athletic event, students should have the opportunity to practice their mathematical skills early and often. For ideas and examples of ready-to-use teaching examples, please visit the Teaching Quantitative Skills in the Geosciences website:

<http://serc.carleton.edu/quantskills/index.html>http://serc.carleton.edu/quantskills/index.html . It's hard to justify to students that they need to take 10+ credits of math if we don't use mathematics in the context of our own courses. As always, please consider uploading your own teaching activities that use any kind of quantitative skills to this growing collection:
<http://serc.carleton.edu/quantskills/teaching_resources/contribute_example.html>http://serc.carleton.edu/quantskills/teaching_resources/contribute_example.html
Cathy Manduca, from SERC, also offers this information about quantitative preparation of students for graduate school (a somewhat different, but related topic):

A couple of years ago a small workshop with faculty and graduate students discussed quantitative preparation of undergraduates thinking specifically about those who would go on to graduate school. You can find the summary here: <http://serc.carleton.edu/quantskills/issues/graduate.html>http://serc.carleton.edu/quantskills/issues/graduate.html.

It includes a nice set of recommendations for departments. They suggest that students going on to graduate school be advised to have

* calculus
* calculus-based physics
* chemistry
* statistics
* programming
* linear algebra

This is of course very different from the question, what math should students have to get an undergraduate geoscience degree. I would frame the answer to this question in terms of what math is essential to complete the degree itself. This follows from the notion that practice using a skill is needed for it to become a useable tool for addressing new problems. So for example, if statistics is a critical skill for geoscientists when they leave the major, I would argue that it would be a skill that you would practice during the completion of your degree, and thus would be an essential prerequisite to something within the majors curriculum.
Best to all, hope these resources are useful…Rock on!
Dave Mogk
Montana State University
