Review

KOLOMYTS EG (2013) *Theory of evolution in snow cover science: atlas monograph*. (Earth Sciences in the 21st Century) Nova Science Publishers, New York. 408pp. ISBN-10: 1-628089-88-1, ISBN-13: 978-1-628-08988-2, hardback US$175

In the mid-1990s I became fascinated with Russian snow science. In the former Soviet Union, snow research was concentrated in the Laboratory of Snow Avalanches and Debris Flow at Moscow State University. The laboratory had been extremely active throughout Russia. I cannot recall exactly how, but on one of my first journeys to Russia, perhaps in Siberia, I obtained three books. One was Bozhinskiy and Losev's (1987; republished 1998) *Fundamentals of avalanche science,* the second was Voytkovskiy's (1977) *The mechanical properties of snow* and the third was Kolomyts's (1977) *Techniques for the crystal-morphological analysis of snow structure*. I passed the books on to my father, a retired Soviet 'analyst' for the American government, who then translated all three books, as well as several papers on avalanche and debris flow dynamics authored by S. Grigoryan, N. Urumbayev and L. Sukhanov.

Clearly, snow science in Russia was highly advanced. For example, the Russians constructed the first full-scale *instrumented* avalanche dynamics test site in the Caucasus in the 1970s, some 30 years before the appearance of any similar test site in Europe. Many Russian scientists, most notably Bozhinskiy and Grigoryan, had a background in solid mechanics and managed to couple mechanical theory to field measurements and observations. I regard Bozhinskiy and Losev (1987) as a concise, well-written and useful book directed to the scientific audience. Frankly, it is my favourite book on avalanches and I wish Bozhinskiy would get more credit for his many good contributions to avalanche science. Voytkovskiy (1977) I use when I need quantitative values for some mechanical properties – strength, cohesion or friction – as a function of temperature and density. The book is somewhat dated now, but it nonetheless remains a useful compendium of mechanical measurements.

Kolomyts (1977) was more difficult to read. It was far more esoteric and overreaching. Here is an example sentence, taken at random: 'Contradictions are the primary factor of evolution in all forms of its manifestation in nature, that is, conflicts arising in the process of the interaction between the geocomponents of any system being examined and the surrounding medium.' What? Well yes, an interesting idea, but not immediately helpful if you are trying to understand snow metamorphism and crystal shape in the snow cover. The reader should in no way take this as a criticism of Kolomyts. There is much to like and I became fascinated with his ideas. I merely want to prepare the interested reader for what is coming: a massive clash of ideas and views. Kolomyts is critical of existing and ongoing snow science, even bitter. In my view, many of his criticisms are justified and should not be ignored. However, at first reading, Kolomyts's book has an 'edge' to it; it is not immediately applicable and is frankly difficult to read, even foreign. Lacking concrete examples and descriptions, I put Kolomyts (1977) aside for several years. Perhaps this was a mistake.

In 2010 I met Kolomyts at a train station in Moscow, just before departing for the Khibinys, which had been a hotspot of avalanche research in Soviet times. At that meeting I gave him my father's translation of *Techniques for the crystal-morphological analysis of snow structure*. Evidently Kolomyts took my father's translation, included several new sections and produced the book at hand, *Theory of evolution in snow cover science*. Many of the chapters are word-for-word translations from my father and these contain few errors. The new sections, however, contain misspellings and bad grammar. The citations are awful and inconsistent. Especially frustrating is that the titles of the Russian references are not translated, making them essentially useless. Again, however, I want to defend Kolomyts. The publishing house should have made an effort to correct these obvious mistakes but did not. There was obviously no editing. This is miserable. The book is careless and sloppy. Again, however, I want to prepare the interested reader: if you are more interested in form than content, the book will clearly disappoint. My father immediately recognized the many errors and was happy that his name was not associated with the book, which is a shame.

But why is Kolomyts so fascinating? Why did I enjoy reading the book, despite these obvious deficiencies? *Theory of evolution in snow cover science* represents some 50 years of Russian research on snow cover and snow metamorphism. Judging from the citations, as well as the date of the snow-cover investigations (e.g. winter 1967/68), most of this work was accomplished between 1950 and 1990, during the Soviet period. There is reference to European and North American snow research, especially after 2000. However, much of this is critical and introduced to highlight the difference between Soviet and Western 'ideologies' of snow. Russian snow science, carried out in a period of Soviet isolationism and the attachment of scientific value to overarching principle, is compared with Western snow science, performed in our present period of inflationary over-publication, hype and just-in-time management. This makes the book captivating, thought-provoking and, well, different and confusing. It is the stuff of the Cold War and the reader is forced to take sides. The book is polarizing: there will be those (a minority) who believe Kolomyts is right and his criticisms of modern snow science are fundamental and justified, and there will be those (a majority) who believe Kolomyts is esoteric, too dogmatic and certainly outdated.

The book is 400 pages long and the first 90 pages are dedicated to crystal morphology. Part I is an 'atlas' of snow crystal shapes, containing magnified pictures of newly fallen snow, proceeding to hexagonal, trigonal, rhombic, columnar, planar prisms and skeletal forms, etc. Each table is dedicated to a particular crystal form. The quality of the pictures is poor. There are hand sketches on each page to highlight surface features, such as facets, tapers, cleavages, cracks, indentations, striations, etc. Text is added to highlight the important crystal features. The crystal pictures are referenced throughout the text to help Kolomyts explain some feature of crystal growth. While reading the subsequent chapters, I found myself continually referring to the crystal features, but still wondering if I was truly identifying the particular feature Kolomyts was trying to highlight. Clearly, any book on snow metamorphism must include a detailed library of crystal forms. However, the book could

be greatly improved by using sharper images with more contrast. I nonetheless recognize and admire the immense and tedious work required to document the wide range of crystal forms that Kolomyts needs to support his theory.

In the next four chapters the book gets interesting. It is this part of the book in which Kolomyts presents his main ideas. In chapter 1, 'Crystal-morphology of snow cover as the object of glaciological research', Kolomyts immediately begins to set himself apart from mainstream (Western) snow science. He maintains that snow-cover models such as Crocus (France) and SNOWPACK (Switzerland) are phenomenological, in that they are rooted in classical thermodynamics (very true). Phenomenological models are effective at determining energy balances, but not the internal structure of the snow cover. Russian models, on the other hand, are based on *probabilistic–statistical* methods and are fundamentally different (and better) than phenomenological models because they can essentially capture the 'internal forces' involved in the evolution of crystal morphology. Phenomenological methods rely too heavily on 'external' causes. Something is missing, because they cannot explain the structural diversity of snow for different boundary conditions. He then recapitulates concepts of 'modern' crystal growth theory, starting from the atomic structure of ice. He adopts many concepts from crystallography, attempting to explain crystal changes with Miller indices and the Gibbs–Curie–Wolf principle. I would agree with Kolomyts that phenomenological methods employ what can only be called empirical relationships to model snow metamorphism, but they are the ideal setting to insert statistical methods. Kolomyts, however, is more than justified in criticizing the lack of well-known crystallography principles in snow studies.

Another criticism that Kolomyts levels at the snow-cover community is that it fails to employ the 'symmetry' principle to understand snow-cover evolution (chapter 2). Crystal growth can only be explained with respect to the symmetry and asymmetry of the driving internal and external forces. This is a unique idea, but standard in crystallography (the Curie principle). Crystal shapes are divided into genotypes (crystal shapes that retain the features of the pure or ideal hexagonal ice form and are therefore symmetric) and phenotypes (crystal shapes that deviate from the ideal form and are therefore asymmetric). If I understand correctly, crystal growth in a pure environment is essentially symmetric. In the snow cover, crystal spacing and random *c*-axis orientations coupled with unidirectional vapour diffusion and temperature fields (called hydrothermal asymmetry) induce the multitude of crystal phenotypes. Concordant and discordant crystal orientations under the same hydrothermal field will evolve to different crystal forms. Reading crystal shape therefore provides 'diverse information' on the surrounding medium, the snow layer.

Chapter 3 demonstrates how external forcing (climate) leads to different snow-cover morphologies. Kolomyts compares different snow covers in different regions of Russia and demonstrates why they exhibit different structural properties. In chapter 4, Kolomyts presents the ideas that give the book its title. He compares snow metamorphism to a biological, evolutionary process where the properties of an individual crystal (ontogeny) become modified. The properties of the crystals are not formed by 'random' variations of the environment, but internal interactions within the snowpack. The internal interactions can be considered 'a struggle' for feed material (water vapour). Of great importance is figure 4.4 which describes Kolomyts's evolutionary development of the crystal individual. The life of a crystal evolves from new snow to fragmented to polyhedral (destructive metamorphism) to facet columnar and planar forms, to semi-skeletal and skeletal forms (constructive metamorphism) and finally to sectorial and plate-like forms (regressive metamorphism). The evolution is unidirectional and characterized by a rigid order of stages that depend only on *time*. For me, the significance of chapter 4 is that if Kolomyts is right, then snow-cover metamorphism can be modelled, and in a way that is completely different from the approaches commonly used in existing snow-cover models.

The remaining chapters present Kolomyts's own modelling approach. The description, however, is difficult to follow. It is not convincing, leaving the book open-ended. Kolomyts often uses the same notation for different quantities (e.g. the letter D) or different notation for the same quantity (e.g. time). Much of the text is repetitive. I wanted to see more examples with more verification. It is a shame that the phenomenological approaches and the evolutionary probabilistic approach of Kolomyts are not combined. After being bombarded with so many new ideas and definitions I needed to pause. This is perhaps my fault, and not the fault of Kolomyts. The book is very dense and is unlikely to be read in one sitting.

Somewhere in the middle of the book, Kolomyts overviews existing snow crystal classification schemes. He writes, 'It is just the trivial truth that is mentioned [in the classification schemes]; the shapes of dry snow particles are determined by water vapour movement at a temperature gradient.' Here and elsewhere in the book, the reader senses Kolomyts's frustration. Simple frustration, however, when born of honesty, has been the starting point of many groundbreaking scientific endeavours. Kolomyts wants more than trivial truths and observations: he wants to develop a general theory of snow metamorphism using well-known principles of mineral crystallography. This is admirable. I very much enjoyed the crystallographic definitions and, while reading, my thoughts continually turned to how crystallographic ideas could be placed within the framework of modern (non-equilibrium) thermodynamics. (I am now reading other books on mineral crystallography. Is this not the purpose of a good book?) In the end, if you are a snow scientist and can share Kolomyts's sense of frustration, then you will find his *Theory of evolution in snow cover science* interesting and, I believe, worthwhile reading. If you are happy with existing empirical theories and 'phenomenological' snow-cover models, then I suggest you pass on this book. I don't think Kolomyts totally succeeds in developing an alternative theory, just as the Soviets did not succeed in developing an alternative political theory to replace capitalism. There are simply too many details and alternatives to consider. The problem is not the overarching idea, but the practical implementation. But this does not mean that Kolomyts is wrong and should be ignored. The book provides a useful framework. This explains why, despite all of the book's imperfections, I greatly enjoyed my time with it.

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