NOAA Teacher at Sea Program
Lesson Plan

Activity Title: What's Age Got To Do With It?

Subject (Focus/Topic): Biology/Environmental Science lesson covering the science behind the aging of fish and how the information can be used in fisheries management.

Grade Level: 9-12

Average Learning Time: Three to six 45-minute class periods (depending on which parts of the lesson are covered and if some is assigned as homework).

Lesson Summary: This lesson has four parts. In Part I, students will learn about the external and internal anatomy of fish by dissecting specimens. They will also locate and examine the otoliths. Part II has the student using pictures of King Mackerel otoliths to determine the age of fish. The concept of the "Tragedy of the Commons" as it relates to global fisheries is explored in Part III. Part IV is a graphing exercise where students will analyze age and gender relationships of two different King Mackerel populations and consider the variety of reasons the population is so structured. These reasons may be a result of a wide range of fishery-dependent or fishery-independent causes.

Overall Concept: In order to manage natural resources, a thorough understanding of the resource such as its physical properties, its distribution and abundance, and causes of variation are needed. A thorough knowledge of these are obtained through the collection and interpretation of scientific data.

Specific Concepts:

1. The age of a fish can be determined by examining the growth "rings" (annuli) on their otoliths.
2. Through the synthesis of scientific observations and data, protection and management of a resource can help prevent a "tragedy of the commons".
3. Based upon the age and gender of fish within a population, age-length keys and age distribution graphs can be created and analyzed. These allow fisheries biologists to better understand the population or stock, and implement restrictions.
4. Age distribution interpretations can show biologists how "healthy" a population is. Is the population declining, threatened, or recovering?

Focus Questions (Specific Questions):

1. What is an otolith and where are they found?
2. How do otoliths help biologists determine the age of a fish?
3. What is the "Tragedy of the Commons" and how can it be prevented?
4. How is age and gender data used to determine the health of a population?

Objectives/Learning Goals:

Part I: Fish Dissection and Otolith Extraction

1. Given a list of external features and internal organs, the student will be able to accurately identify 90% of them on the specimen he/she has dissected.
2. The student will be able to extract at least one of the two otoliths in one piece.
3. The student will be able to describe the relationship between a fish's otoliths and lateral line.

Part II: Aging Fish Using Otoliths

1. Given images of otoliths, the student will be able to accurately age 75% of those given.

Part III: Fisheries and the Tragedy of the Commons

1. The student will devise two strategies designed to prevent the destruction of a common resource.

Part IV: Using Data to Understand Fisheries

1. The student will use the provided data sets for two different King Mackerel populations, to create Length-at-Age Keys and Age Structure graphs with 80% accurately for each population.
2. The student will interpret these diagrams to determine which one of the two fishery populations has greater health (least likely to experience declines due to overfishing).

Background Information:

Part I: Fish dissection and otolith extraction

It may be beneficial for students to have a rudimentary understanding of fish anatomy. Previous experience with dissection would be helpful, especially for the portion of the lab where they are extracting the otoliths. When removing otoliths, it is very easy to probe too deeply and cause them to fall in toward the top of the head. Once this happens, the otoliths are extremely difficult to remove and should be left within the fish.

If Greek and Latin root words, prefixes, and suffixes are taught in class, students could attempt to determine what the term "otolith" means. Once the word has been dissected, a class discussion could ensue where students determine where otoliths are located in fish.

Part II: Aging Fish Using Otoliths

Teachers can conduct a pre-activity discussion on how scientists can determine the age of various objects. Possible answers include: tree rings, lake varves, radiocarbon dating (as well as other radiometric data methods). Often during the "summer" portion of the rings, there will be several dark, very closely spaced rings. Students may have a tendency to count each one as a separate year.

Part III: Fisheries and the Tragedy of the Commons

None specific to this activity.

Part IV: Using Data to Understand Fisheries

Students need good graphing skills. Some students may not be familiar with the concept of a "Best Fit Line", especially those that aren't linear. Both the logarithmic and exponential lines may need to be modeled - possibly the instructor could do the first of each kind of line (on the Atlantic population graph) with the students as a class exercise.

Common Misconceptions/Preconceptions:

Part I: Fish dissection and otolith extraction

Due to the misnomer of "ear bones", students may believe that otoliths are true bones. Otoliths are more properly described as "ear stones"; oto- = ear and -lith = stone. They are composed of calcium carbonate ($CaCO_3$) which is the common mineral composing the sedimentary rock limestone.

Part II: Aging Fish Using Otoliths

Students may expect the otoliths to have a uniform, easily discerned structure with a distinct core or center similar to tree cookies. It may take them several otoliths to feel comfortable with counting the annuli by themselves. The instructor may want to count some of the otolith images together. The following slides are suggested as examples of Good (#8), Average (#3), and Poor (#7) otolith samples.

Part III: Fisheries and the Tragedy of the Commons

None identified.

Part IV: Using Data to Understand Fisheries

Students may erroneously believe that factors influencing populations are cut and dried. Most factors are interrelated in one way or another and usually, no clear connection can be pinpointed as a cause. In this exercise, they are encouraged to explore several reasons and try and make those connections.

Materials:

- Student worksheet (entire packet or selected parts depending upon desired learning targets)
- Dissection equipment (one per student group)
    - Dissecting tray
    - T-pins
    - Forceps
    - Scalpel
    - Scissors
    - Ruler
    - Probe
- Dissecting microscope (one per group)
- 1/2 Petri dish (per group)
- Small container of dark colored wood stain
- Otolith PowerPoint presentations
    - Guide to Ageing King Mackerel Otolith Sections
    - King Mackerel Ageing Exercise
    - King Mackerel Ageing Exercise Key
- Goldfish crackers
- Large plastic bowls (one for each group)
- Straws (one per student)
- Ruler
- Graph paper
- Colored pencils

Technical Requirements:

The PowerPoint presentations require a projector and/or Smart Board (or similar device) so that the entire class can view them.

One of the anticipatory activities (for part II), requires that computers have the latest version of Adobe Flash. This activity can be done as an individual exploration of aging using otoliths, or can be completed as a group during class.

Teacher Preparation:

Part I:

If the instructor has never removed an otolith from a fish, they should practice dissecting the specimen and removing the otoliths prior to teaching the lesson. Otherwise, general lab preparation and set up of materials is required.

Part II:

Prior to the activity, the instructor should view all three presentations in order to become familiar with them and to anticipate any parts that may cause their students difficulties.

- "The Guide to Ageing King Mackerel Otolith Sections"
- "King Mackerel Ageing Exercise"
- "King Mackerel Ageing Exercise Key"

Part III:

General lab preparation is required: assemble materials and set up lab stations.

Part IV:

General preparation: copy materials and gather supplies. Pre-activity discussions can be conducted concerning environmental influences on populations; examples are density-dependent and –independent factors, human influences on the environment, etc.

Keywords:

- Otolith
- Tragedy of the Commons
- Age Distribution Graph

Pre-assessment Strategy/Anticipatory Set:

Part II: As a class or individually, students can go through the Age Reading Demo (ARD) found at the Alaska Fisheries Science Center. http://www.afsc.noaa.gov/refm/age/interactive.htm The following species' otoliths are the easiest to age and offer the least complicated introduction to ageing: Atka Mackerel, Pacific Cod, Walleye Pollock - GOA, and Yellowfin Sole.

Lesson Procedure:

This lesson can be completed in its entirety or each part can be done independently at different times throughout the year as it happens to fit within the curriculum.

Part I:

Divide class into groups of 2-4 depending upon materials/supplies available. Students will continue to work together in the same groups throughout the dissection portion of this lesson.

Each group will first examine and identify the various features of a fish's external anatomy. This is easily done on a short day since there is no actual dissection involved.

On day 2, the students will be dissecting the fish and identifying the various internal organs. As they dissect the fish, they will answer the questions as they go.

Discuss the word origin of "otolith" and brainstorm on what they are and why fish have otoliths. On day 3, the students will work on extracting the otoliths and examining them under a dissecting microscope. When students have removed the otoliths and are trying to examine them under the dissecting microscope, it may be easier for them to see the annuli if they are stained. Using a small Styrofoam paint brush, lightly coat the otolith with a small amount of dark colored wood stain (brand is not important). Allow it to dry before taking it back to the microscope. Gently blot any drips of stain.

Part II:

Show the initial PowerPoint presentation: "Guide to Ageing King Mackerel Otoliths". Have students take notes as they view the presentation. This exercise can be performed as either an individual activity or in pairs.

Optional: As a class, the following interactive website can be explored as a class: Age Reading Demo (ARD) found at the Alaska Fisheries Science Center. http://www.afsc.noaa.gov/refm/age/interactive.htm

Pass out the student handouts/worksheet. As students view each individual slide in the PowerPoint presentation "King Mackerel Ageing Exercise", they should count the annuli on each otolith presented. In addition to counting the annuli, they are to categorize each otolith

as to its "readability" level of "good", "average", or "poor". Finally, each otolith viewed should have some sort of comment entered into the data table. This can be something about why they gave it a certain readability rating, any distinctive patterns or lack of annuli, shape or breaks in the actual otolith itself, or any difficulties they had.

After viewing the Ageing Exercise presentation, students will answer the questions that follow.

Part III:

Pass out the lab and arrange the class into groups of 3-4 students. Each group will sit in a circle around a table with their "ocean" in the center of the table. Every student in the group needs to have equal access to the "ocean".

Go through the background information about the "Tragedy of the Commons" together as a class and brainstorm what resources might be considered a "commons".

Carefully time each fishing session and monitor the class to ensure that everyone is following the rules of play. Upon completion of Round One, replenish each "ocean" and instruct the students about how the rules have changed for the second round. After both fishing rounds have been completed, if you want, divvy up the remaining goldfish crackers amongst the students for them to snack on while they answer the analysis questions.

Part IV:

Read through the background materials together, stopping periodically throughout to discuss the concepts covered. Again, this activity can be completed either individually or in pairs with each student being responsible for creating both graphs for one of the populations.

After the graphs are complete (this may take one day in itself), students will analyze their graphs and answer the questions relating to them as well as the hypothetical graph included at the end.

Assessment and Evaluation:

Summative Assessments:

Parts I, II, III, and IV: Lab activity packets can be turned in for a grade (see attached answer key). Students should be able to complete these questions with a 75% accuracy.

Formative assessments:

Part I: Either in a bell ringer or exit ticket format, students should be able to identify both external and internal organs of a fish with an 80% accuracy.

Part II: Either in a bell ringer or exit ticket format, students should be able to correctly age 75% of given otolith sections.

Part III: Either in a bell ringer or exit ticket format, students should be able to:

- Devise two strategies to prevent the destruction of a common resource.
- Apply these strategies to fisheries and suggest a minimum of two viable solutions.

Part IV: Either in a bell ringer or exit ticket format, students should be able to:

- Create a Length-at-Age key and/or an Age Structure diagram for a given population with 80% accuracy
- Interpret the health or viability of a fish stock when given a hypothetical Length-at-Age key and an Age Structure diagram.

Standards:

National Science Education Standards Addressed:
Content Standards, Grades 9-12

- Content Standard A: Science As Inquiry
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- Content Standard C: Life Science
  - Interdependence of organisms
  - Matter, energy, and organization in living systems
  - Behavior of organisms
- Content Standard E: Science and Technology
  - Understandings about science and technology
- Content Standard F: Science In Personal and Social Perspectives
  - Population growth
  - Natural resources
  - Environmental quality
  - Science and technology in local, national, and global challenges
- Content Standard G: History and Nature of Science
  - Science as a human endeavor
  - Nature of scientific knowledge

Ocean Literacy Principles Addressed:

- The Earth has one big ocean with many features.
  - Fundamental Concepts: h
- The ocean supports a great diversity of life and ecosystems.

    - Fundamental Concepts: h
- The ocean and humans are inextricably interconnected.
    - Fundamental Concepts: b, e, and g
- The ocean is largely unexplored.
    - Fundamental Concepts: b, c, and e

Wyoming State Science Standards Addressed:

- Grade 11:
    1. Concepts and Processes: Science is a dynamic process; concepts and processes in life systems, earth and space systems, and physical systems are best learned through inquiry and investigation. Students develop an understanding of scientific content through inquiry within the context of these unifying concepts and processes:
        - Systems, classification, order, and organization
        - Evidence, models, and explanations
        - Change, constancy, and measurement
        - Evolution and equilibrium
        - Form and function

        SC11.1.4 Interdependence of Organisms: Investigate the interrelationships and interdependence of organisms, including the ecosystem concept, energy flow, competition for resources, and human effects on the environment.

        SC11.1.5 Matter, Energy, and Organization in Living Systems: Describe the need of living systems for a continuous input of energy to maintain chemical and physical stability. Explain the unidirectional flow of energy and organic matter through a series of trophic levels in living systems. Investigate the distribution and abundance of organisms in ecosystems, which are limited by the availability of matter and energy and the ability of the living system to recycle materials.

    2. Science as Inquiry: Students demonstrate knowledge, skills, and habits of mind necessary to safely perform scientific inquiry. Inquiry is the foundation for the development of content, teaching students the use of processes of science that enable them to construct and develop their own knowledge. Inquiry requires appropriate field, classroom, and laboratory experiences with suitable facilities and equipment.

        SC11.2.2 Students use inquiry to conduct scientific investigations:
        - Pose problems and identify questions and concepts to design and conduct an investigation.
        - Collect, organize, analyze and appropriately represent data.
        - Give priority to evidence in drawing conclusions and making connections to scientific concepts.
        - Clearly and accurately communicate the result of the investigation.

SC11.2.3: Students clearly and accurately communicate the results of their own work as well as information from other sources.

SC11.2.4: Students investigate the relationships between science and technology and the role of technological design in meeting human needs.

SC11.2.5: Students properly use appropriate scientific and safety equipment, recognize hazards and safety symbols, and observe standard safety procedures.

3. History and Nature of Science in Personal and Social Decisions: Students recognize the nature of science, its history, and its connections to personal, social, economic, and political decisions. Historically, scientific events have had significant impacts on our cultural heritage.

   SC11.3.2 Students examine how scientific information is used to make decisions:
   - Interdisciplinary connections of the sciences and connections to other subject areas and career opportunities.
   - The role of science in solving personal, local, national, and global problems.
   - The origins, limitations, and conservation of natural resources, including Wyoming examples.

Next Generation Science Standards (NGSS) - (based on May 2012 draft - subject to change with future revisions):

- HS.LS-IRE: Interdependent Relationships in Ecosystems
  - LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
    - There are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain.
  - LS2.C: Ecosystem Dynamics, Functioning, and Resilience
    - A complex set of interactions within an ecosystem can keeps its numbers and types of organisms relatively constant over long periods of time under stable conditions.
    - Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
    - Anthropogenic changes can disrupt an ecosystem and threaten the survival of some species.
  - LS4.D: Biodiversity and Humans
    - Humans depend on the living world for the resources. Human activity is having adverse impacts on biodiversity through overexploitation.
- HS.LS-NSE: Natural Selection and Evolution
  - LS4.C: Adaptation

        - Changes in the physical environment, whether naturally occurring or human induced, have contributed to expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline - and sometimes the extinction of some species.
    - HS.ESS-HS: Human Sustainability
        - ESS3.A: Natural Resources
            - Resource extraction has association economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.
        - ESS3.C: Human Impacts on Earth Systems
            - Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.
            - Scientists and engineers can make major contributions. Human activities can be regulated to mitigate impacts.
            - Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities and changes in human activities.
- HS-ETS-ED: Engineering Design
    - ETS1.B: Developing Possible Solutions
        - When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.
    - ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World
        - Analysis of costs, environmental impacts, risks and benefits, are critical aspects of decisions about technology use.

Common Core

- English Language Arts (ELA):
    - RST.9-10.7: Translate quantitative or technical information expressed in words in a test into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
    - RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
    - SHST.9-10.1: Write arguments focused on discipline-specific content.
    - WHST.9: Draw evidence from informational texts to support analysis, reflection, and research.

- Mathematics:
    - MP1: Make sense of problems and persevere in solving them.
    - MP.2: Reason abstractly and quantitatively.

- MP.5: Use appropriate tools strategically.
- N-Q: Reason quantitatively and use units to solve problems.
- S.ID: Summarize, represent, and interpret data on a single count or measurable variable.
- S.IC: Make inferences and justify conclusions from sample surveys, experiences, and observational studies.

Additional Resources:

- Florida Fish and Wildlife Conservation Commission, Introduction to Aging Fish: What are Otoliths?
- Anatomy of a Fish coloring page (also has a short aging exercise using scales): http://www.biologycorner.com/worksheets/fishcolor.html
- Macromedia flash interactive covering external and internal fish anatomy:
  - External: http://www.aquaticcommunity.com/anatomy/external.php
  - Internal: http://www.aquaticcommunity.com/anatomy/internal.php
- Fun, quick interactive computer game demonstrating the Tragedy of the Commons using a "bunny farm". http://www.bunnygame.org/
- NOAA Fisheries primer: http://afrf.org/primer3/
- Alaska Fisheries Science Center Age and Growth Program: http://www.afsc.noaa.gov/refm/age/Default.htm
  - Age Reading Demonstration (ARD): http://www.afsc.noaa.gov/refm/age/interactive.htm
  - Age Determination of Fish FAQs: http://www.afsc.noaa.gov/refm/age/FAQs.htm

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Carrie Fioramonti
Doug DeVries.

Creation date: September 2012

Name: _____ Class Period: _____

What's Age Got to Do With It?
Part I: Fish Dissection and Otolith Extraction

Objectives:

- Given a list of the external features and internal organs of a fish, be able to identify 90% of both (external and internal) accurately in your dissected specimen.
- Be able to locate where an otolith is found in a fish and successfully remove them intact (in one piece).
- Be able to describe how a fish's otoliths and lateral line are used for movement throughout the water column.

Background:

Fish are the largest group of vertebrates found in both freshwater and marine ecosystems. Around 50% of the vertebrate population is made up of more than 25,000 species of fish. They are extremely successful animals due to their adaptations to life in aquatic environments.

The fish in the class Osteichthyes have bony skeletons. There are three groups in Osteichthyes -- ray-finned fish, lobe-finned fish, and the lung fish. The fish you will be dissecting is an example of a ray-finned fish. Its fins have spiny rays of cartilage &/or bone to support them. These help the fish move quickly through the water and steer without rolling.

In this lab, you will observe the external and internal structures of a fish. You will see how these structures make it suited to living in an aquatic environment.

Materials:

- Preserved fish
- Lab apron
- Safety glasses
- Gloves
- Dissecting tray
- Dissection kit: forceps, scalpel, scissors, probe, ruler
- Flexible tape measure
- T-pins
- Small labels for flagging pins
- One half of a Petri dish
- Dissecting microscope

Safety Precautions:

- Wear closed toed shoes since sharp objects are used in this lab.
- Wear safety glasses to protect your eyes from any fluids that may squirt from the fish.
- Wear a lab apron and gloves.
- Scalpels are sharp!
    - Do not cut towards yourself.

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- Do not point them at others. When passing it to your partner, hand it to them handle first.
- Do not run with them.

Procedure:

Part A: External Anatomy

1. Thoroughly rinse and pat dry the specimen. Place it in the dissecting pan with its head on the left.
2. Label the anterior, posterior, dorsal, and ventral sides of the perch on Figure 1.

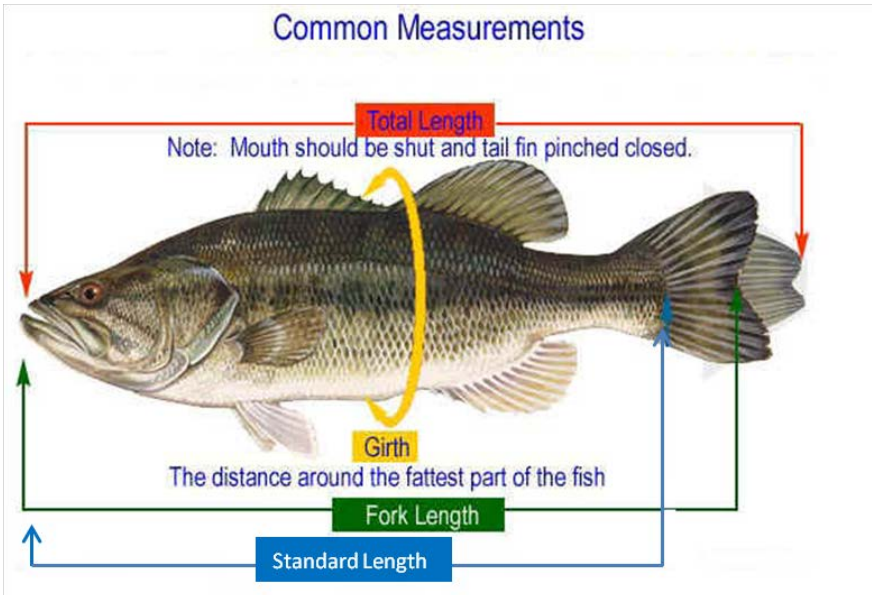

Figure 1

3. Using the ruler and flexible tape measure, determine the total length, fork length, standard length, and girth of your fish. Record this in Table 1.

Table 1: Fish Measurements (mm)

Total Length	
Fork Length	
Standard Length	
Girth	

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4. Locate all the external structures as show in Figure 2.

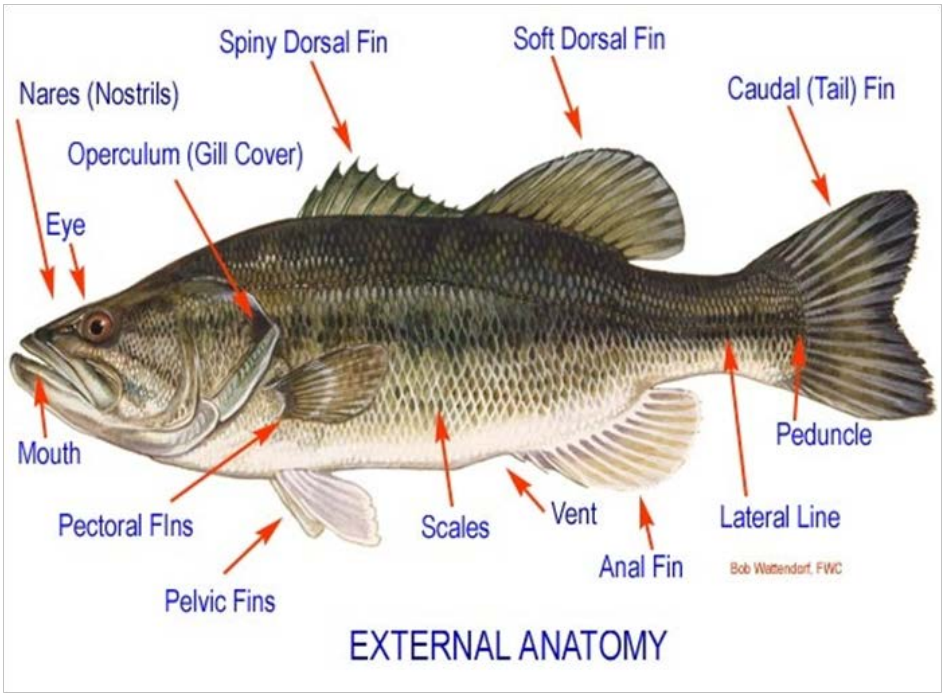

Figure 2: External Anatomy
(Source: Florida Fish and Wildlife Conservation Commission)

5. Place labeled, flagged T-pins in the structures you've located on the fish. Before proceeding, have your teacher verify that you've correctly identified the structures.
6. Describe the general body shape of the fish. In what way does the shape allow for life in the water?

7. Look closely at the fish's scales.
8. Describe the scales of the fish. Which direction do they face? What is the advantage of this?

Similar to tree rings, scales show rings that indicate the age of a fish. Rings that are farther apart form during the summer when food is abundant and the fish is growing quickly. Closely spaced rings form in winter when the fish grows slowly. These patterns are recorded on each individual scale. (There are several rings per scale.) The core (region near the base of the scale where the rings originate) formed when the fish was a fry. Those near the edge are the most recent. (See Figure 3.)

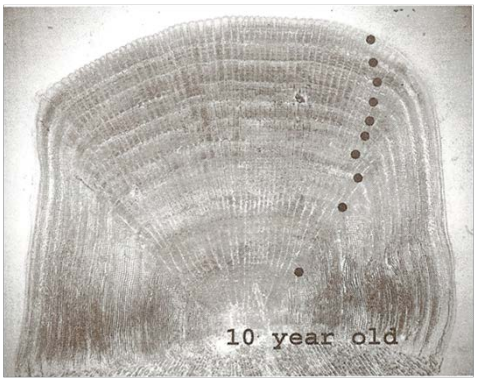

Figure 3: Striped Bass fish scale (source: John Boardman , MA Division of Marine Fisheries.
http://www.striperspace.com/facts.html

Name: _____

9. Sketch and describe what the scales from your fish look like under magnification. If you can see rings, count them and try to determine the age of your fish. How old is it?

10. Color the yearly rings on the simulated fish scale in Figure 4. How old would this fish be?

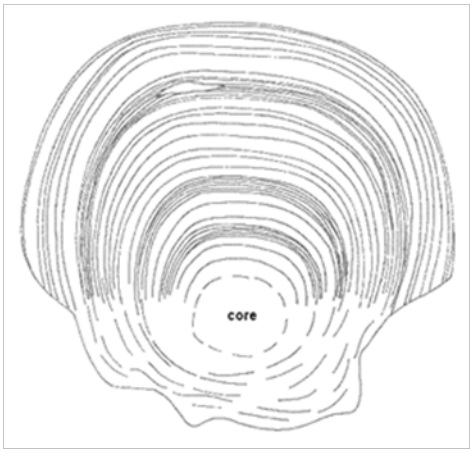

Figure 4: Simulated Fish Scale
(Source: http://www.biologycorner.com/worksheets/fishcolor.html)

11. Gently spread the fins so they are fanned out. Looking at the fins, complete Table2.

Table 2: Fins

Name of Fin	Spines (Y/N)	Number of Fins	Location	Function
Anterior Dorsal				
Posterior Dorsal				
Caudal				
Anal				
Pelvic				
Pectoral				

12. Open and close the fish's ***mouth*** to observe the jaws.
13. Are both jaws equally moveable? Explain your answer.

14. Examine the teeth.
15. What shape are the teeth? What direction do they point?

16. Explore the inside of the ***nares*** (nostrils) with the probe.
17. How many nares does the fish have? How are they different from your nostrils?

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18. Examine the fish's eyes.
19. Do they have eyelids? Why do you think this is?

20. Place the probe into the fish's mouth and gently push it out the back opening of the ***operculum***. Use the probe to "prop" the operculum open. Look inside at the gills. You should be able to see several ***gill arches*** as shown in Figure 5.
21. How many gill arches are located on each side?

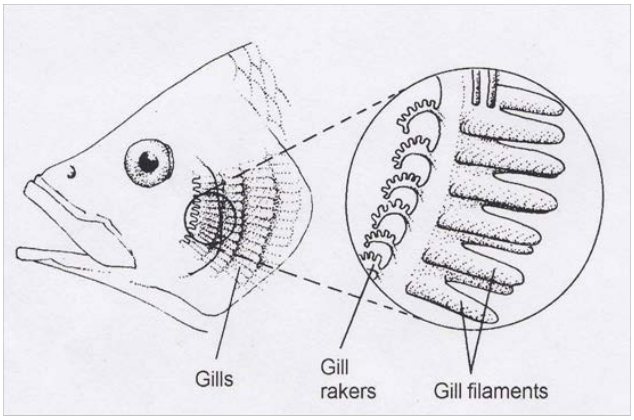

Figure 5: Gills

22. Cut the dorsal and ventral attachments of one gill arch and remove it.
23. Place the gill arch in a small Petri dish filled partially with water and look at it with the dissecting microscope. Look at the thin, feather-like structures called ***gill filaments*** (Figure 5).
24. What characteristics (you should be able to think of at least two) can you see in the gills that make them an efficient respiratory organ?

25. Locate the ***gill rakers*** on the gill arch (Figure 5). They help separate the gill arches, creating spaces between them. Look at the other gill rakers still attached to the fish; notice how they project forward into the fish's mouth.
26. What could be one function of the gill rakers?

27. Trace the ***lateral line*** along the fish's length. Describe the lateral line. What is its function?

Part B: Internal Anatomy

1. Using your scalpel, begin your incisions. Be careful to not cut too deeply; you don't want to accidentally damage any of the internal organs. Follow the incision order in Figure 6. Make sure you make the incisions in the exact order and directions shown in the diagram.

Name: _____ Class Period: _____

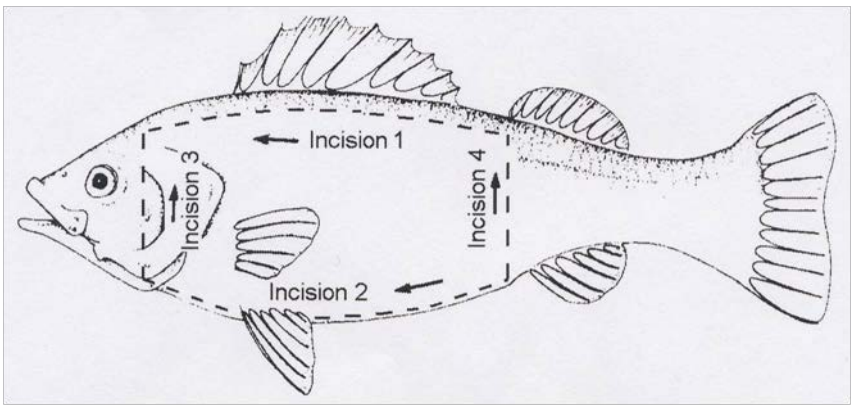

Figure 6: Dissection Incisions

a. For incision 1, cut along the dorsal side of the fish just above the lateral line.
b. Incision 2 should begin on the ventral side of the fish just in front of the ***vent*** (anus).
c. When you reach the operculum, (you'll most likely need to switch to scissors to cut this hard structure), cut upward behind the gills. This is incision 3.
d. Finish removing the body wall by making incision 4. Place the scalpel inside the vent and cut upward toward incision 1.
e. As you lift the side of the fish away from the body, you may need to cut any membranes attached to the body wall.
f. If any organs are covered in fat, use the forceps to remove it.

2. Using Figure 7, locate the internal organs. Place labeled, flagged T-pins in the organs as you locate them.

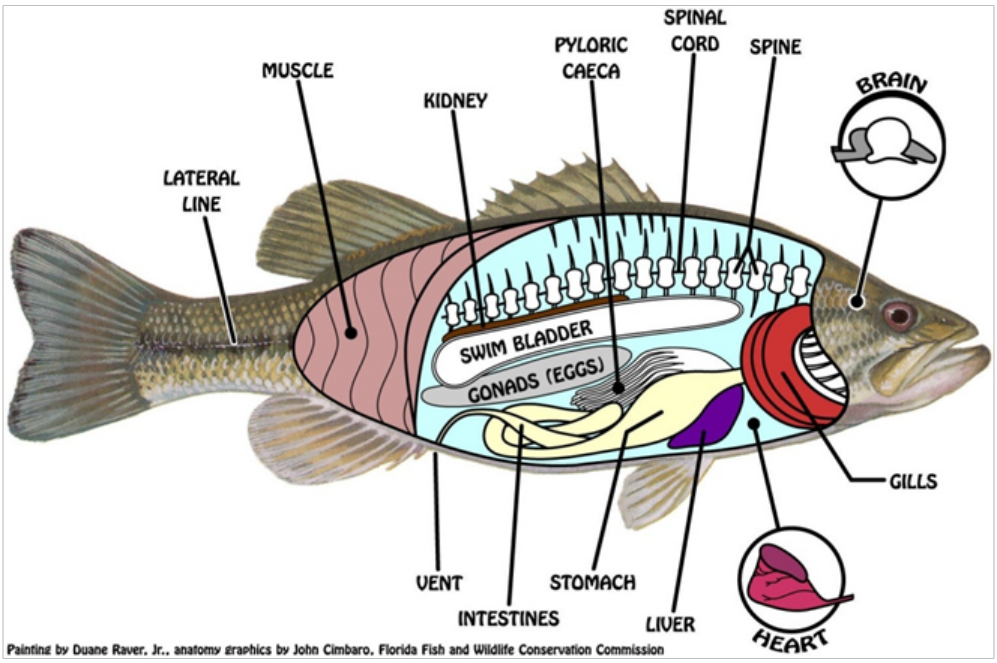

Figure 7: Internal Anatomy
(Source: Florida Fish and Wildlife Conservation Commission

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3. Locate the ***liver*** in the front of the body cavity; it is a pale tan color.
4. The ***liver*** is part of which body system? What is its function?

5. Find the ***stomach***. Gently push it aside and look for some fine, tubular structures. These are the ***pyloric caeca***.
6. In which body system is the ***stomach***? What is its function?

7. At the posterior end of the stomach, you'll be able to see the coiled ***intestines***.
8. The ***intestines*** are part of which body system? What is their function?

9. In front of the liver and behind the gill rakers is the pericardial cavity containing the ***heart***. The heart has only two chambers: an atrium and a ventricle. Try to identify each of them. (You do not need to label them.)
10. Which body system is the heart? What is the ***heart's*** function?

11. In the upper portion of the body cavity, below the lateral line is the ***swim bladder***. It is a very thin-walled organ. Most likely it is deflated and all you'll see is a void with a thin membrane across the back of the body cavity. Label this with a T-pin.
12. What is the function of the ***swim bladder***?

13. Below the swim bladder and to the posterior of the body cavity, you'll find the ***gonads (testes or ovaries)***. If the fish was close to spawning, you may be able to see fine, round eggs in the gonads indicating your fish is a female. Depending on its reproductive stage, you may or may not be able to determine the sex of the fish.
14. Locate the two, long, dark ***kidneys*** in the posterior of the body cavity.
15. In which body system are the ***kidneys***? What is their function?

16. The tail has no organs; it is a muscle. Why do think this is?

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Part C: Otolith extraction:

Once you have dissected the fish and identified all of its organs, you can now begin to extract the otoliths. Follow the procedure below to do this:

1. Slice the underside of the fish's head so that the jaws are free from the body. DO NOT take the head entirely off! (See Figure 8.)

2. Placing your left hand inside the fish's jaws and the right hand at the base of the cut by the gills, pull the head backwards. The motion is as if you are trying to lay the top of the fish's head onto its back. This will expose the brain case. DON'T completely remove the head! (See Figure 9.)

3. You should now be able to see the brain case in the exposed center of the fish's head. (See Figure 10.)

Figure 8: Slicing the underside of the head

4. Using a pair of diagonal cutters (dikes), snip the brain case near the front of the head and also near the rear of the head. Then, using a chisel, pop the underside of the brain case away from the head. (See Figure 11.)

Figure 9: Exposing the brain case.

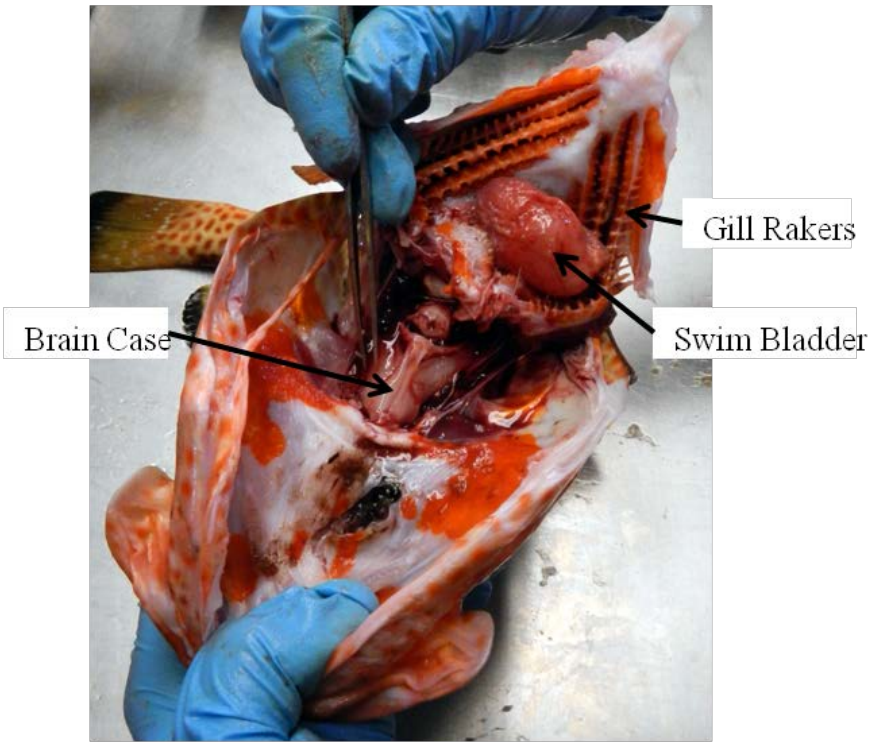

Figure 10: Exposed brain case and organs inside head.

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5. Once the brain case is removed, you should see a series of openings leading into the fish's head. The otoliths are located in the outermost slots on each side of the brain case.

6. Using forceps, gently reach into the cavity and feel for a small object - the otolith (this is very similar to the game "Operation"). Carefully grab the otolith and pull. Because there are fluids inside the head, the otoliths may slip back inside. Repeat the process if needed to remove the otolith. If you probe too deeply, you could potentially push the otolith deeper until it can no longer be retrieved. Once you've removed one otolith, repeat the procedure on the opposite side. (See Figure 12.

Figure 11: Removing the brain case.

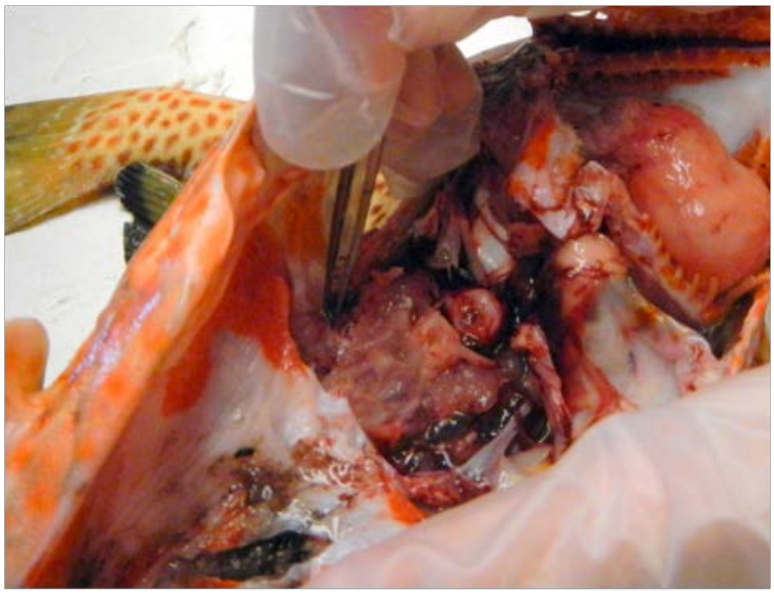

Figure 12: Removing an Otolith

7. Carefully pat the otoliths dry and place them in a dry Petri dish. Examine them under the dissecting microscope.
8. Sketch and describe the shape of the otolith. Can you see any rings? If you can, how old do you think the fish is?

9. Take the otoliths to your teacher and have them lightly stained. Return to the dissecting microscope and look at them. Now do you see any rings? If so, how old do you think the fish is?

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Part II: Aging Fish Using Otoliths

Objectives:

- Given images of otoliths, be able to accurately age 75% of those given.

Background:

Otoliths are commonly referred to as "ear bones"; this term is not technically correct, because they are not true bones. They are more accurately called "ear stones" since they are composed of calcium carbonate ($CaCO_3$). They are located near the base of the fish's skull (Figure 1). Otoliths increase in size on a yearly basis; usually they accrete less in winter and more during the summer. Their purpose is to help the fish sense gravity and acceleration as well as maintain its balance.

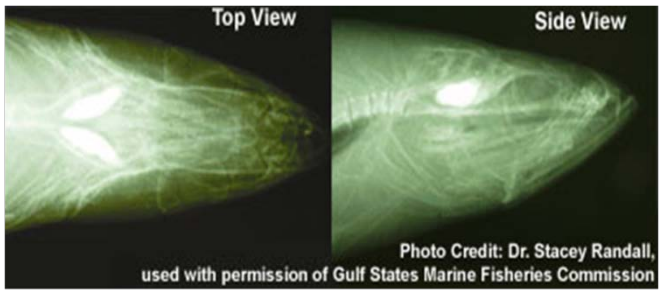

Figure 1: X-ray view of otolith placement.
(Source: Florida Fish and Wildlife Conservation Commission
http://myfwc.com/research/saltwater/fish/age-growth-lab/aging-fish-otoliths/

There are three types of otoliths in fish (Figure 2), and all three help it detect sound. Otoliths exist in pairs and are located near the brain. Each type has a specific function. The **sagitta** (the largest of the three) is also involved in converting sound waves into electrical signals the brain interprets as sounds allowing the fish to hear. In addition, the **asteriscus** helps with the hearing process, and the **lapillus** also detects gravitational force.

Figure 2: Three types of otoliths.
(Source: Otolith Research Laboratory,
http://www.marinebiodiversity.ca/otolith/english/what.htm)

The fish uses the otoliths in conjunction with its lateral line to determine how it should move through the water column. Fish move toward or away from a stimulus with may be sensed through sound. The lateral line system allows the fish to detect movement and vibrations in the water. These senses help the fish navigate their environment.

The shape and size of otoliths vary with fish species (Figure 3). Fish from reefs or rocky bottoms (e.g. snappers and groupers) tend to have larger otoliths than fish that spend most of their time swimming at high speed in the open ocean (e.g. tuna and mackerel). Sometimes, different fish species can be identified by their distinct otolith shape.

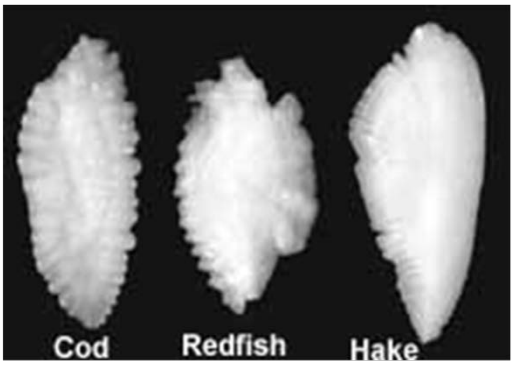

Figure 3: Different fish species have a variety of otolith shapes and sizes. (Source: Otolith Research Laboratory,
http://www.marinebiodiversity.ca/otolith/english/what.htm)

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There are several methods used by biologists to age fish. They can use scales, bones, fin rays, and otoliths. These all form yearly rings (annuli - plural and annulus - singular) similar to those of a tree. Of all these aging methods, otoliths give the most accurate ages.

Counting the annuli on an otolith can be very difficult; they are often not clearly visible. Many different environmental factors and stresses can cause complex features that interfere with being able to easily see each annulus. These factors include such things as water temperature, salinity, and other chemical properties of the water; food supply; and population density.

Reading otoliths requires LOTS and LOTS of practice! Not every line is a growth ring; only those that are very distinct tend to be an annulus. Those closest to the center of the otolith are spaced the furthest apart, while those nearest the edge become closer and closer together. Older fish are easier to age than young ones because of the spacing.

Materials:

- PowerPoint presentation: Guide to Ageing King Mackerel Otolith Sections
- PowerPoint presentation: King Mackerel Ageing Exercise

Procedure:

1. View the presentation: Guide to Ageing King Mackerel Otolith Sections. Take notes while viewing this - you will need them to answer the questions that follow.
2. View the presentation: King Mackerel Ageing Exercise. Each slide in this presentation if of an otolith section viewed through a microscope. There are 30 different otoliths.
    a. As you view each slide, count the annuli to determine the age of the fish. Enter the age to determined in the data table.
    b. While counting the annuli, you'll be able to tell the quality of the otolith section by how easily you can see each "ring". Classify the readability as "Good", "Average", and "Poor" and enter this in the data table.
    c. You need to enter a comment for each sample aged. This could be something like details you noticed about the otolith such as distinctive patterns (other than the rings), the shape of the otolith section viewed, difficulties, or what made the ageing process easy.

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Otolith Ageing Data Sheet

Sample #	Age	Readability Code (G, A, P)	Comment
KMK 1b			
KMK 2b			
KMK 3c			
KMK 4c			
KMK 5a			
KMK 6a			
KMK 7c			
KMK 8a			
KMK 9b			
KMK 10b			
KMK 11a			
KMK 12b			
KMK 13a			
KMK 14a			
KMK 15c			
KMK 16a			
KMK 17b			
KMK 18b			
KMK 19b			
KMK 20a			
KMK 21b			
KMK 22a			
KMK 23c			
KMK 24c			
KMK 25b			
KMK 26b			
KMK 27a			
KMK 28c			
KMK 29c			
KMK 30b			

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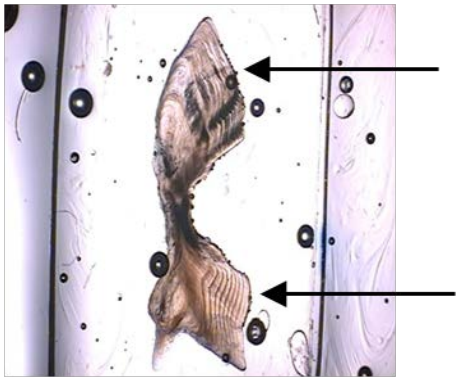
Analysis:

1. On the diagram of the King Mackerel saggita below, label the following parts: dorsal and ventral.



2. Describe a couple of reasons why annuli have more growth in the summer time and less growth in the winter.

3. Why might a biologist choose to use fish scales to age a fish instead of their otoliths? Would the age they get be as accurate as if they used otoliths? Why or why not?

4. After completing this aging exercise, how confident do you feel in aging fish? Would you want to be an otolith reader? Why or why not?

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Part III: Fisheries and the Tragedy of the Commons

Purpose:

To explore how resources are used and exploited when they are available to multiple parties.

Objective:

- Harvest as many fish as you can without destroying the fishery.
- Use your experience to understand the conditions that lead to the "tragedy of the commons".
- Devise strategies to prevent the destruction of a common resource.
- Apply these strategies to fisheries and suggest solutions.

Background:

The Tragedy of the Commons:

The concept that air, water, and fish are held in common for use by all was first codified into law by the Romans in 535 AD. The use of common resources is a tricky issue . . . who has rights to it? How are the responsibilities shared?

This idea was first clearly developed and given a name by Garrett Hardin in 1968; since then, it has become a cornerstone of ecology and environmental science. The basis of this concept lies in the unchecked use of a "common" resource. If a resource is considered to be owned by everyone (held in common), then ultimately the resource will be destroyed; thus, the "tragedy".

When Garrett Hardin proposed this concept, he used the example of the traditional "commons" in New England towns to represent a public resource available for private gain. In early American New England, the commons were a central pasture used for grazing of livestock owned by the towns people. He showed that a small increase in use of the resource (e.g., one extra cow) provides a great benefit to the individual. However, the cost of that additional use (decreased available grass) is shared by all. Therefore, each user has an incentive to use (exploit) the resource to the greatest of his/her ability. Ultimately, this leads to decreasing yields for both the group and the individual.

This idea has been used to explain the pattern of exploitation of many common, limited resources. For example, the exploitation of wild populations (overfishing), abuse of public lands (overgrazing of federal lands), degradation of the environment (air pollution), and population growth can all be evaluated using this principle. Even situations in your school can be explained by the tragedy of the commons. Can you think of a few examples?

To this end, strategies such as laws, incentives, privatization, communication, and education have been developed to counter act the natural tendency toward overuse. With these options, common resources can be protected and communities can work toward sustainable resource use. Several of these will be explored in this activity.

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Materials:

- Goldfish crackers
- Large plastic bowls (one for each group)
- Straws (one per student)

Procedure:

1. Divide yourselves into groups of four. Each group will sit in a circle around the plastic bowl or "ocean" filled with goldfish crackers.
2. The crackers represent resources that can be harvested from the "ocean". Each goldfish cracker is worth $10. The more fish you catch, the more money you will make.
3. To fish, you must retrieve the cracker from the bowl by sucking it from the "ocean" with the straw.
4. You will have the opportunity to fish once a year (which lasts one minute) to determine your income.
5. It is your choice how many fish you take. However, you must catch at least ***ONE*** fish per year to keep from going bankrupt.
6. Each fishing session represents one generation of fish.
7. The fish in the "ocean" will reproduce once a year. Each fish is able to reproduce and make one new fish. (If four fish remain, after one year, you would have eight fish for the next fishing year).
8. The carrying capacity of the lake is 16 fish.
9. Keep the fish you catch on the table in front of you.
10. **A bonus will be given to the student in each group who has made the most money at the end of the entire simulation.**

Round One:

Blind fishing - No Talking Allowed!

Year #	# Fish at Beginning of Year	# Fish taken Fisherman #1	# Fish taken Fisherman #2	# Fish taken Fisherman #3	# Fish taken Fisherman #4	Total Fish Left at End of Year
1	16					
2						
3						
Total	xxx					xxx
$$ Earned (total x $10)						xxx

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Round Two:

Open fishing - Free Exchange of information encouraged!

Year #	# Fish at Beginning of Year	# Fish taken Fisherman #1	# Fish taken Fisherman #2	# Fish taken Fisherman #3	# Fish taken Fisherman #4	Total Fish Left at End of Year
1	16					
2						
3						
Total	xxx					xxx
$$ Earned (total x $10)						xxx

Analysis:

1. What happened to the fish (common resource) in Round 1? Why do you think this happened?

2. Explain the rationale for your fishing technique in Round 1.

3. What factors lead to uncertainty in this round?

4. Did anyone in your group take too many fish? How did that make you feel?

5. Did everyone try to take as many fish as possible? Why or why not?

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6. Did you get the same or different results in Round 2? Why?

7. Explain the rationale for your fishing technique in Round 2.

8. What concerns/strategies were raised by other members of your group during Round 2? Briefly relate your discussion.

9. Did each member of the group stick to the plan?

10. If you cooperated with the other fishermen in your group, what was the result of that cooperation?

11. Did anyone sacrifice the number of fish for the good of the group? Why or why not?

Reflection Questions:

1. Your fish harvest was worth money. Why would it be better to have money than fish (i.e. what can you do with money that you can't do with fish)?

2. Is it possible to maximize the number of fish caught per person ***AND*** the number of fish remaining in the ocean at the ***same time***? Why or why not?

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3. Does society ever reward people who sacrifice a resource for the good of the community? What might a reward for their sacrifice look like?

4. Does society reward those with the "most"? Explain your answer.

5. Would it make a difference to know what the rewards of resource management are prior to using the resource? Why?

6. Why does common usage lead to exploitation?

7. Think of a ***local commons*** that you are familiar with (parking lots, cafeteria, bathrooms, etc.). Do similar situations arise? Explain. How might these problems be solved?

8. What other ocean resources could be exploited besides fish?

9. The Earth's oceans are a global commons. In your opinion, are they being used wisely? Why or why not?

10. Based upon your experience in this exercise, ideally, what would be the best ways to manage fisheries and other ocean resources?

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Part IV: Using Data to Understand Fisheries

Objectives:

- Using the provided data sets for two different King Mackerel populations, accurately create Length-at-Age Keys and Age Structure graphs for each.
- Interpret these diagrams to determine which of the two fishery populations has greater health (least likely to experience declines due to overfishing).

Background:

Fish are a renewable resource. This means that they replenish their populations naturally, and as long as restrictions are in place, they can be harvested on a continuous basis. However, if the harvest of fish exceeds the population's ability to reproduce and maintain its numbers, the population will begin to decline and possibly become extinct.

So why do biologists want to know the age of fish? By knowing the age of fish caught (either by commercial/recreational fishermen or fisheries biologists), fisheries managers can better understand how fish stocks interact with their environment. Combining growth studies along with age data, biologists can improve their understanding of things like the timing and magnitude of spawning, recruitment and habitat use, larval and juvenile duration, and population age structure. With laboratories being able to conduct increasingly complex chemical analyses, biologists can discover things about fish such as the year they hatched and their migration routes. Knowing this type of information allows biologists to monitor and manage stock for long-term health. All of this information, when combined, is important for designing appropriate fisheries management policies.

To maintain a healthy fish population, wildlife biologists conduct stock assessments of various populations. So, what is a fish stock? It is a population unit selected for management or harvesting purposes. Often times, there a several population units for each fish species. In this activity, we will be looking at data from two different stock of King Mackerel: the Atlantic population and the Gulf of Mexico population.

There are two stock assessment methods that fisheries biologists utilize to determine the health of a population. These methods are based on the fishery and/or the biology of the species. If the analysis of a stock is centered around data supplied by fisheries, it is called fishery-dependent. If the data is collected by biologists, it is called fishery-independent data.

Fishery Based Assessment: In this type of assessment, adequate historical fishing data must be available. Not only does the quantity of fish caught and landed each year need to be accurate, but data revealing the amount of effort expended by fishermen must also be considered.

Data for a fishery based assessment may be incomplete or unreliable. For example, it is difficult to compare the effort exerted, because fishing technologies are continually improving. For example, earlier fishermen may have used a single sailboat that could only pull one net. Modern fishermen may be driving a diesel-powered ship with multiple nets. New technologies

such as sonar and GPS make it easier to locate the desired fish stock; therefore, harvesting fish becomes easier and easier.

Biology Based Assessment: This assessment revolves around the age the species of fish spawn. Another question is what percentage of all the fish caught are between the ages of one and three? For example, if the average age that the species begins to spawn is three-years, some of the fish may begin spawning at the age of two. But, what if most of the fish harvested are two-years old? There would be a possibility that too many fish would be caught before they could spawn and replace themselves, leading to recruitment overfishing. One step that can be taken by fisheries managers is to implement size limits. Limiting the catch of smaller sized fish allows a greater number to survive to spawning age. However, this still doesn't guarantee overfishing won't occur.

There is no way that the health of an entire species' population can be completely assessed. If a truly thorough assessment were to be made, both fishery-dependent and fishery-independent information of the species would need to be collected. According to Wallace and Fletcher in "Understanding Fisheries Management: A Manual for Understanding the Federal Fisheries Management Process, Including Analysis of the 1996 Sustainable Fisheries Act":

The following information about the fishery would need to be:

1. The kinds of fishermen using the fishery (trawlers, charter fishermen, recreational anglers, etc.)
2. Pounds of fish caught by each kind of fishermen over many years.
3. Fishing effort expended by each kind of fisherman over many years.
4. The age structure of the fish caught by each group of fishermen.
5. The ratio of males to females in the catch.
6. How the fish are marketed (preferred size, etc.)
7. The value of the fish to the different groups of fishermen.
8. The time and geographic area of the best catches.

Biological information would need to include:

1. The age structure of the stock.
2. The age at first spawning (recruitment).
3. Fecundity (average number of eggs each age fish can produce).
4. Ratio of males to females in the stock.
5. Natural mortality (the rate at which fish die of natural causes).
6. Fishing mortality (the rate at which fish die from being harvested)
7. Growth rate of the fish.
8. Spawning behavior (time and place).
9. Habitats of recently hatched fish (larvae), of juveniles and of adults.
10. Migratory habits
11. Food habits for all ages of fish in the stock.
12. Estimate of the total number or weight of fish in the stock.

However, in the "real world" most of this data is not available. Analysis of fish stocks then relies upon the "best available data". Some of the most useful data used to assess a stock are the relationship between fish length/age and the ages of fish in a stock. From this data, wildlife

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biologists can determine the growth and death rates of the fish. Earlier in this exercise you used otoliths to determine the age of a King Mackerel population. Using age data collected from otolith analysis and the lengths of all the fish caught, a Length-at-Age Key can be created. The age data can also be used to create an Age Structure Diagram. Of course, for both of these methods, the larger the sample size, the more reliable the fish stock projections.

Length-at-Age Key: This type of graph is useful for estimating the age of a fish based on its length. This is especially valuable when otolith data is not available. The change in the length and weight of the population from year to year can be used to estimate the species' growth rate. One drawback is that growth rates tend to slow down dramatically the older the fish gets, so this method becomes less useful for older fish. At this point, another aging method must be used. For example, in Figure 1, it would be difficult to determine the age of a 20-inch fish because it could be between 4 and 8 years old. Because of this, for older fish, it is definitely better to rely upon other aging methods.

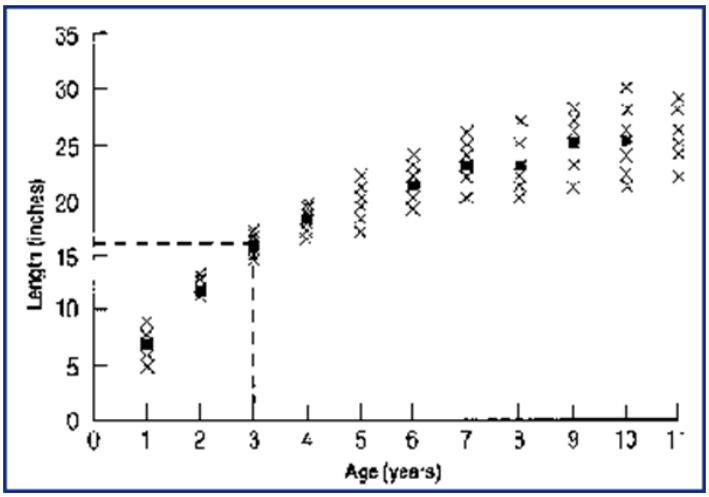

Figure 1: Length-at-Age Key
(Source: Understanding Fisheries Management, http://nsgl.gso.uri.edu/masgc/masgch00001.pdf)

Age Structure: This diagram is a type of "historic" picture of the stock (Figure 2). Age structures provide a picture of the fish stock as it exists today, and if the species is long-lived, some information about the stock's history can be explored. Biologists cannot take their interpretations of the age structure diagram and tell specifically what caused any declines, but they can make some inferences about the history of the population. There are several things that can be learned by studying an age-structure diagram.

1. The age at which fish are first harvested.
2. How old the species tends to live.
3. The number of fish at each successive age. This pattern can tell about harvesting trends over several seasons.
   a. Gaps in the age structure indicate different times the population has declined.
4. Backward projections can sometimes give an idea as to how many fish in each age group may have existed at a given point in time (Figure 3).

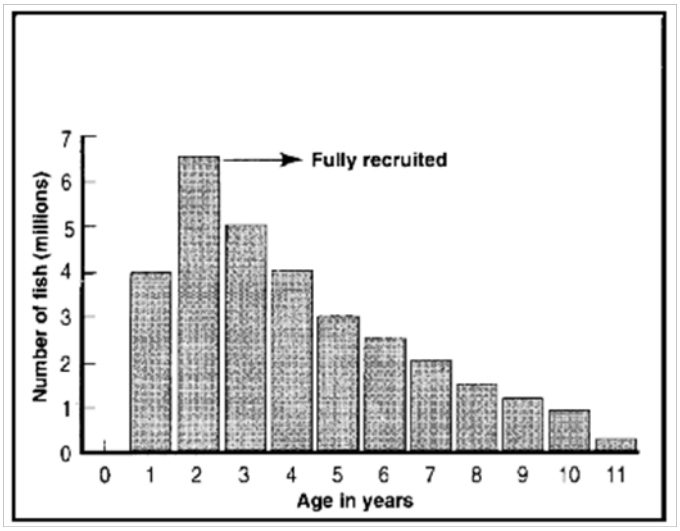

Figure 2: Age Structure Diagram
(Source: Understanding Fisheries Management, http://nsgl.gso.uri.edu/masgc/masgch00001.pdf)

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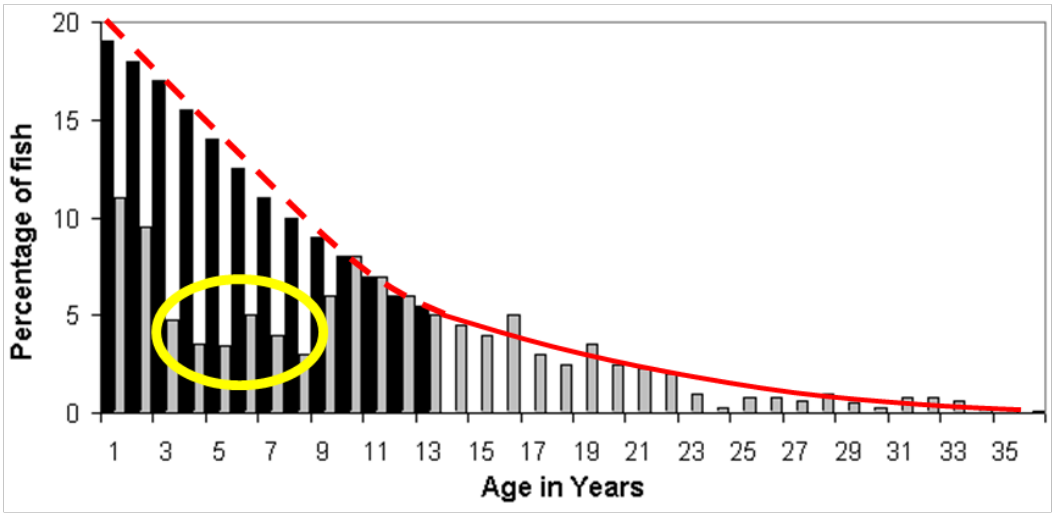

Figure 3: Age Structure with Backward Projection (black bars), Gap in Population (circled area). (Source: Understanding Fisheries Management, http://nsgl.gso.uri.edu/masgc/masgch00001.pdf)

Materials:

- Graph paper
- Ruler
- Colored pencils

Procedure:

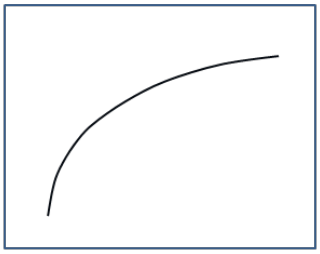

Figure 4: Logarithmic line

1. Complete the data tables for each of the King Mackerel populations.
    a. Round your calculated percentages to the ***nearest*** whole number. (Remember, your total percentage may/may not add up to 100% because of rounding.)
2. Create a the following diagrams for each of the populations (Atlantic and Gulf of Mexico). To set up your graphs, refer to Figures 1 and 2 for axis orientation.
    a. Length-at-Age Key.
    b. Age Structure
3. On each of the Length-at-Age Key diagrams, draw a logarithmic best-fit trend line similar to that in Figure 4. This means it doesn't pass through every single data point, but represents a "smooth" average of the data.
4. On each of your Age Structure diagrams, create a backward projection by drawing an exponential curve similar to that in Figure 3.

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Table 1: Atlantic King Mackerel Population

Age	Average Length (mm)	Total Number	% of Population
1	631	19	
2	701	62	
3	792	51	
4	840	40	
5	898	18	
6	937	17	
7	948	13	
8	943	8	
9	1066	8	
10	1030	7	
11	---	0	
12	---	0	
13	1285	1	
14	1180	1	
15	1140	1	
16	---	0	
17	1030	1	
18	---	0	
19	1239	1	
20	---	0	
21	---	0	
22	1240	1	
	Totals:		

Table 2: Gulf of Mexico King Mackerel Population

Age	Average Length (mm)	Total Number	% of Population
1	611	30	
2	713	65	
3	767	47	
4	825	27	
5	889	13	
6	966	14	
7	1012	13	
8	1112	11	
9	1074	7	
10	1110	6	
11	1120	8	
12	1186	4	
13	1190	1	
14	---	0	
15	1375	1	
16	---	0	
17	1390	1	
18	1300	1	
19	---	0	
20	---	0	
21	---	0	
22	---	0	
	Totals:		

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Application Questions:

1. Looking at the Length-at-Age Keys that you made for both populations, answer the following questions:
    a. At what length do you think that you could no longer successfully predict the fish's age?

        i. Atlantic population:

        ii. Gulf of Mexico population:

    b. Is there any age range where you see great variation in the average length of the fish population?

        i. Atlantic population:

        ii. Gulf of Mexico population:

    c. Why do you think this might be?

    d. Which of the two populations show greater variation in the length of older fish? Why do you think this is?

2. Looking at the Age Structure diagrams you've constructed, answer the following questions.
    a. At what age are King Mackerel from both populations beginning to be harvested?

    b. What is the maximum age for fish in the:

        i. Atlantic population?

        ii. Gulf of Mexico population?

    c. Are King Mackerel a short- or long-lived species?

Name: _____ Class Period: _____

d. Assuming that female King Mackerel don't begin spawning until four years of age what might you predict about the future health of the King Mackerel fisheries? Are they healthy? In decline? Recovering? Hint: Think about the size of the pre-spawning population compared to the population older than four years.

   i. In the Atlantic?

   ii. the Gulf of Mexico?

e. The populations appear to have the maximum numbers of fish in the second and third years. Why do you think that there are significantly fewer one-year old fish represented in both populations? Hint: Think about fisheries management practices.

f. Do you see any gaps in either of the populations that might indicate a decline at one time or another? If so, using a colored pencil, draw brackets around the region.

g. Now, draw an exponential line making a backward projection for each of the populations. Use a different color of pencil than you used to indicate the declines in population. Substitute numbers of fish in millions for the percentages on each of the Age Structure diagrams (e.g. 5% = 5 million, 20% = 20 million). Based upon the line you've drawn, how many one year old fish might exist within these populations?

   i. Atlantic?

   ii. Gulf of Mexico?

3. Based on the analyses of the two King Mackerel populations you've just done, which of the two do you think has a greater "health"? Explain why you chose this one.

Name: _____ Class Period: _____

4. Using the diagram below (Figure 5), answer the following questions:

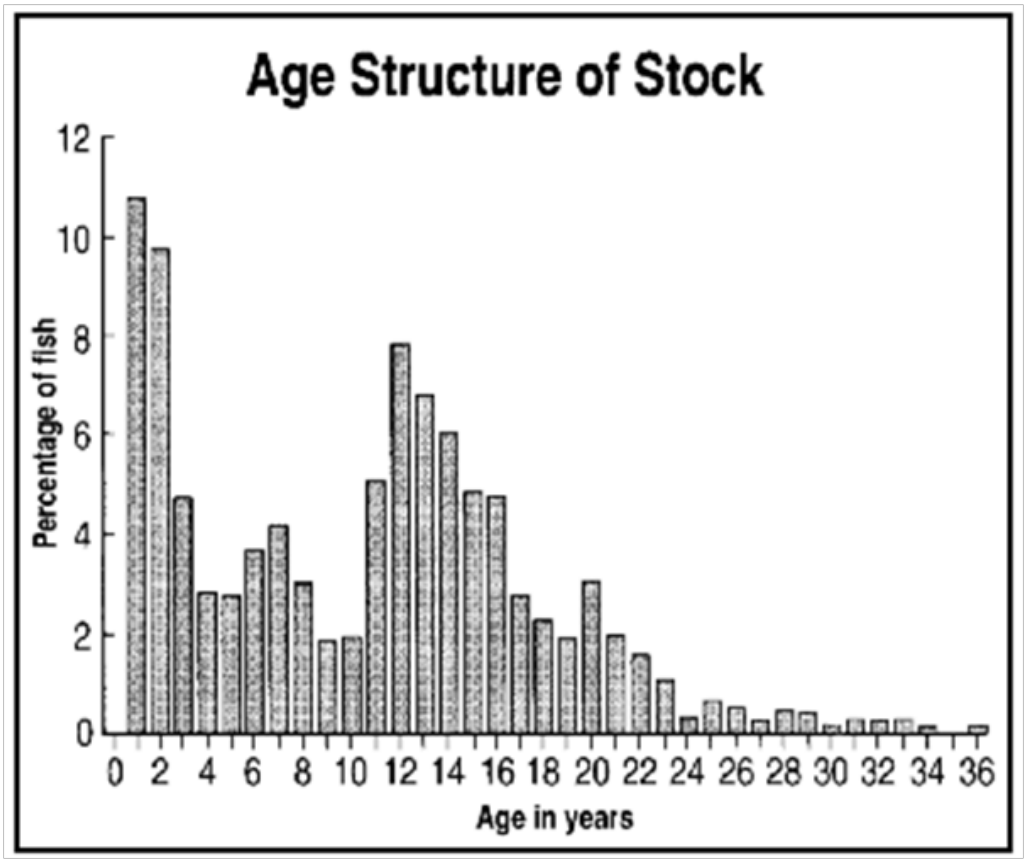


Figure 5: Age Structure of a Hypothetical Fish Stock (Source: Understanding Fisheries Management, http://nsgl.gso.uri.edu/masgc/masgch00001.pdf)

a. At what age are the fish beginning to be harvested?

b. How old was the oldest fish harvested? Is the species short- or long-lived?

c. If the 11-year old fish were hatched in 1975, when were the 3-year old fish hatched?

Name: _____ Class Period: _____

d. The number of fish at each successive age (two to three, three to four, etc.) does not follow a smooth downward trend like that in Figure 2. Using a colored pencil, bracket the places on the age structure diagram where there are definite declines in the population. What do you think may have caused these? List at least three reasons relating to fishing practices and at least three reasons relating to natural events/disasters.

e. Using a second color, draw an exponential curve on Figure 5 creating a backward projection of the population. If you don't remember what the backward projection might look like, refer back to Figure 3. Start at age 36 when creating your line and continue through ages 17 and 11 back to the y-axis.

f. Based on your line, what percentage of the population should fish with an age of 8 years old be?

g. Looking at your curve, there appears to be a spike in the fish population from ages 12-16. Why do you think this spike may have occurred? Hint: think about the population decline(s) that you bracketed.

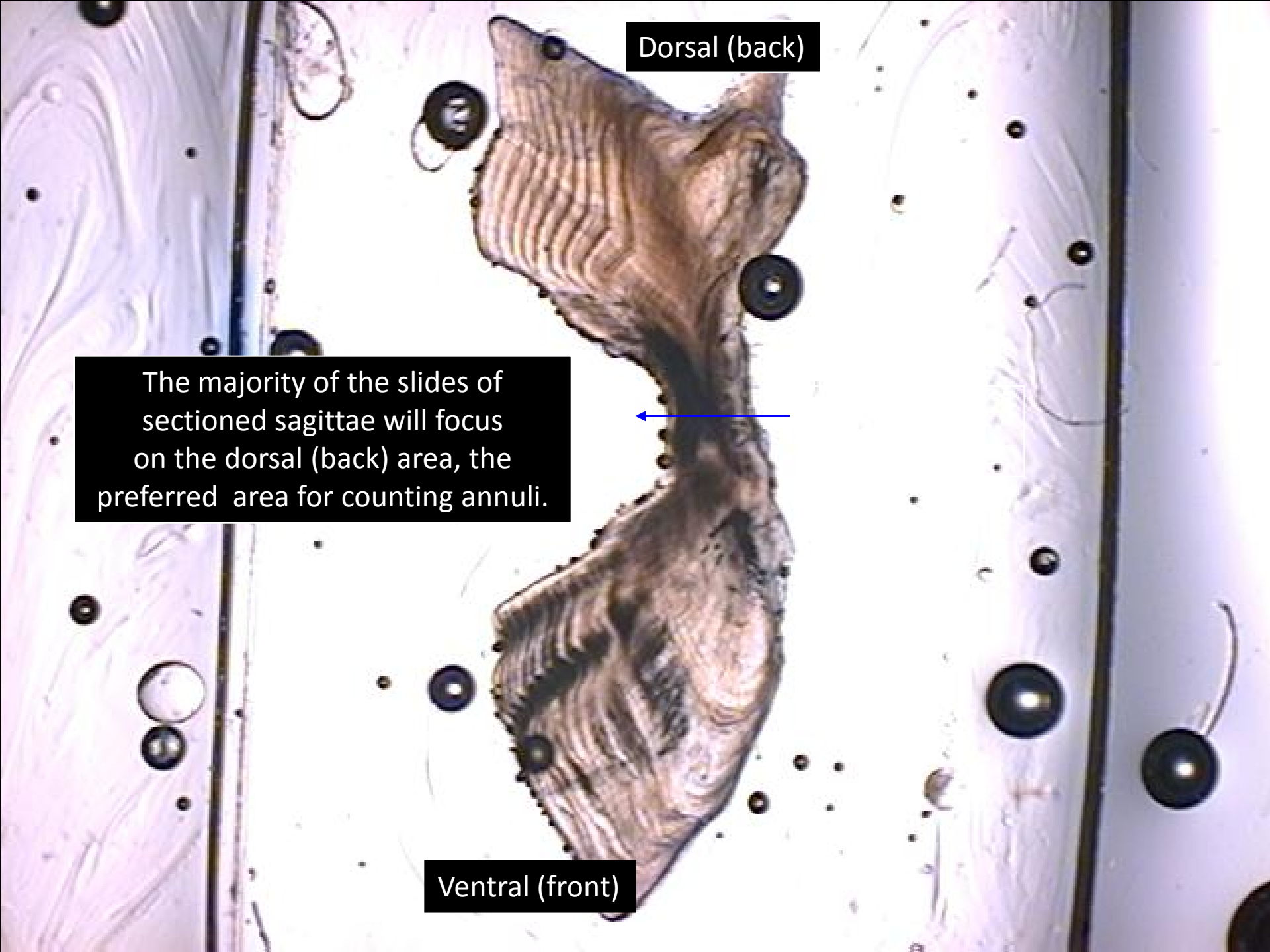
Guide to Ageing King Mackerel Otolith Sections

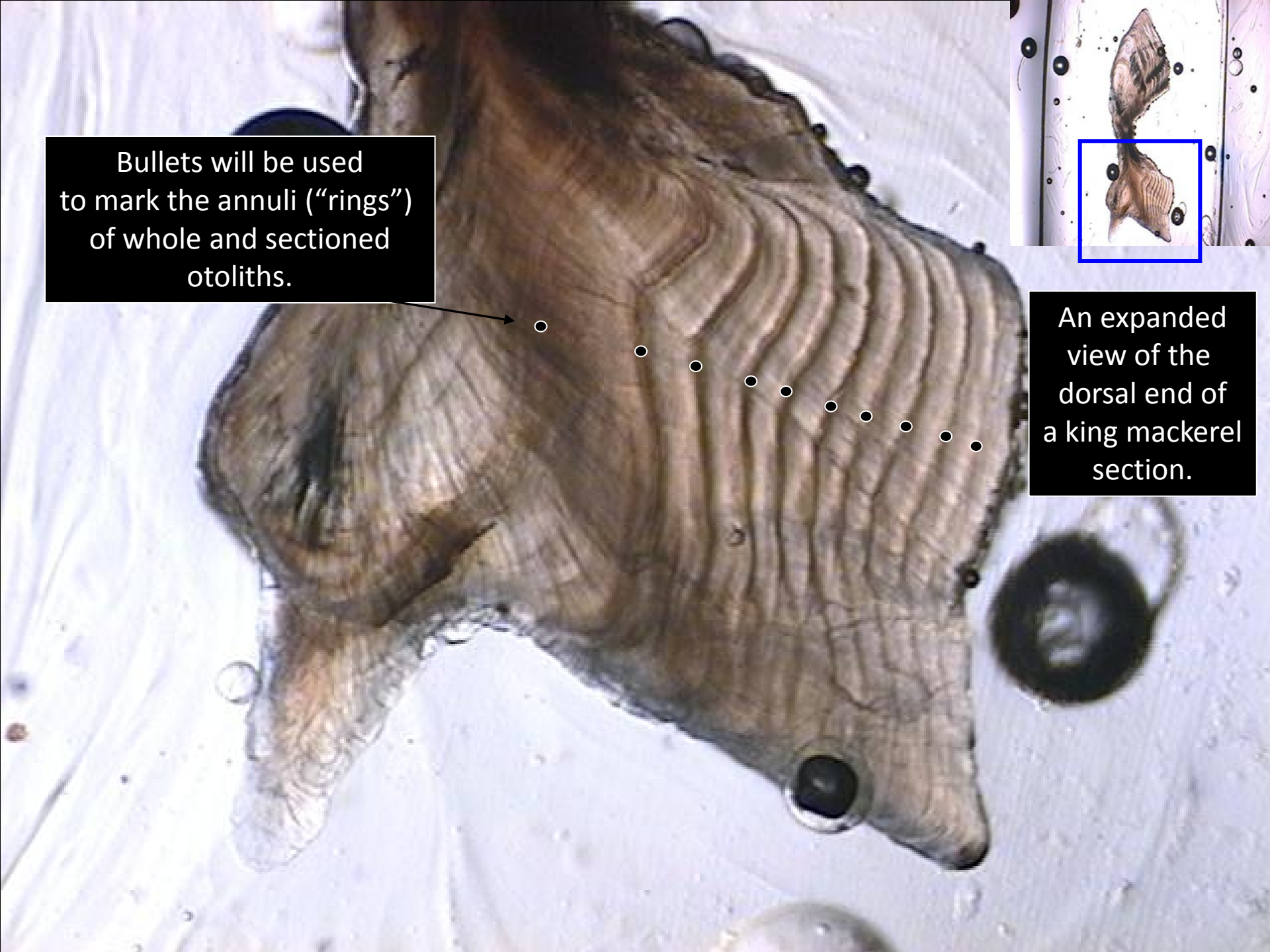
From ACCSP Mackerel Ageing Guide

Published by NOAA Fisheries

Panama City Laboratory

View as slideshow for animation


Dorsal (back)
The majority of the slides of sectioned sagittae will focus on the dorsal (back) area, the preferred area for counting annuli.
Ventral (front)

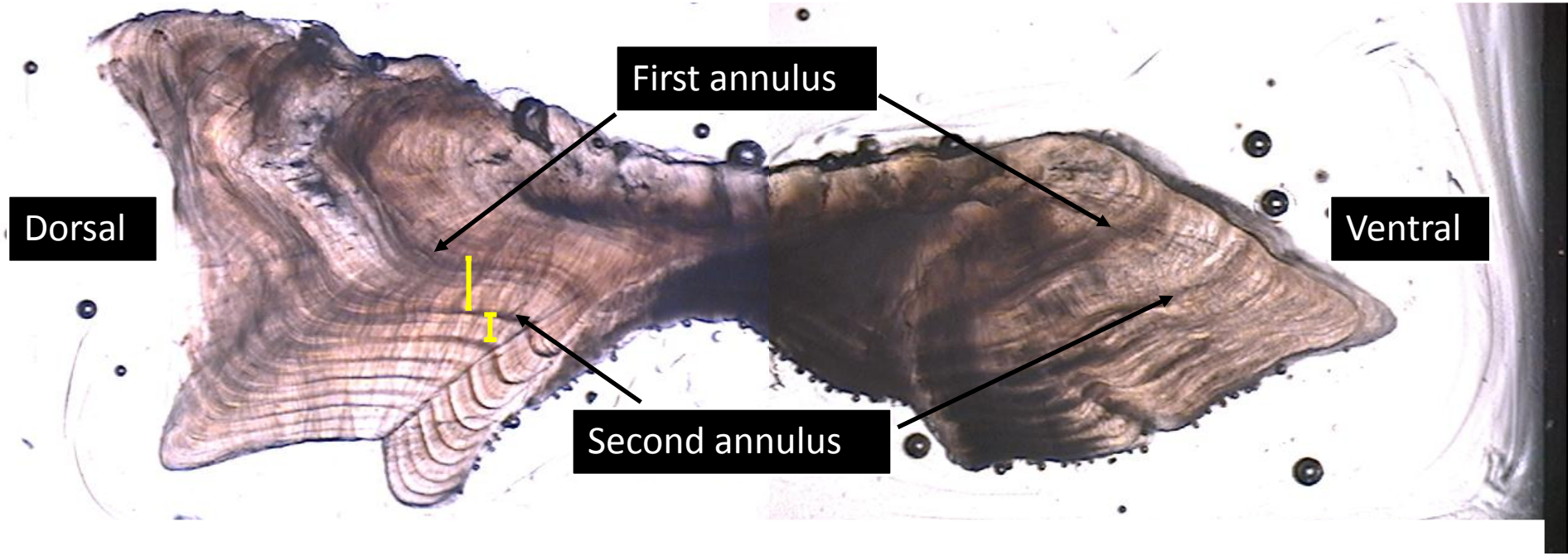

Bullets will be used to mark the annuli (“rings”) of whole and sectioned otoliths.
An expanded view of the dorsal end of a king mackerel section.

IDENTIFYING
THE FIRST ANNULUS

SECTIONED SAGITTAE

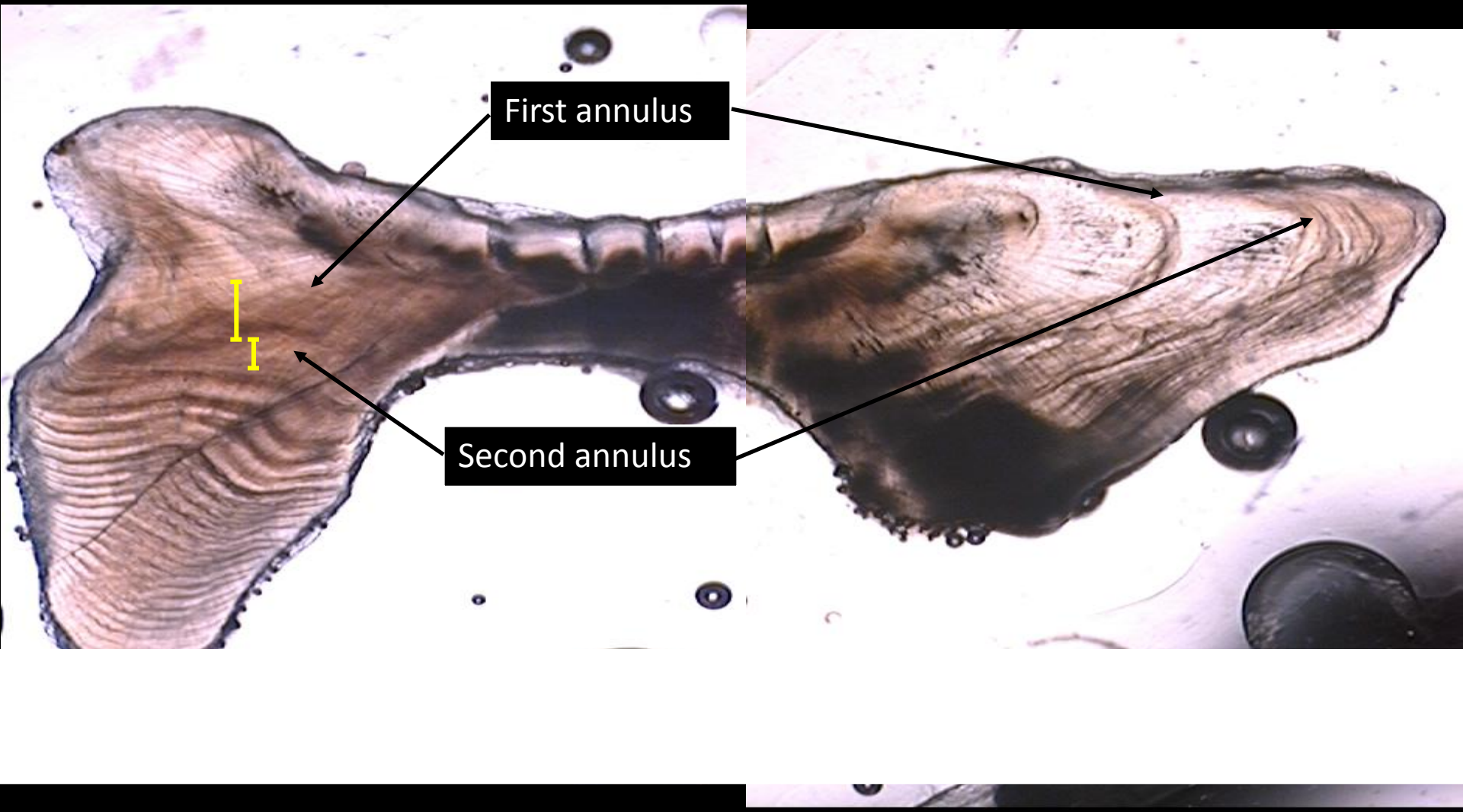
- In most fish, the first annulus ("ring") in a sectioned sagitta ***usually*** appears as:
  - A broad, diffuse (spread out), dark band
  - Or a composite of several very closely spaced bands
- Frequently is quite faint
- Often has a ridge-like appearance along its distal (far) edge

In this section from a 10 year old 109 cm female king mackerel, one can see the broad, diffuse, band-like characteristics of the first annulus at the dorsal end. This section also demonstrates the usefulness of examining the ventral end to verify the location of the first annulus at the dorsal end.



This section also shows typical annulus spacing. The first increment is by far the largest. The second, between the first and second annulus, is smaller but still considerably larger than any subsequent ones, which all tend to be very similar in size regardless of the age of the fish.

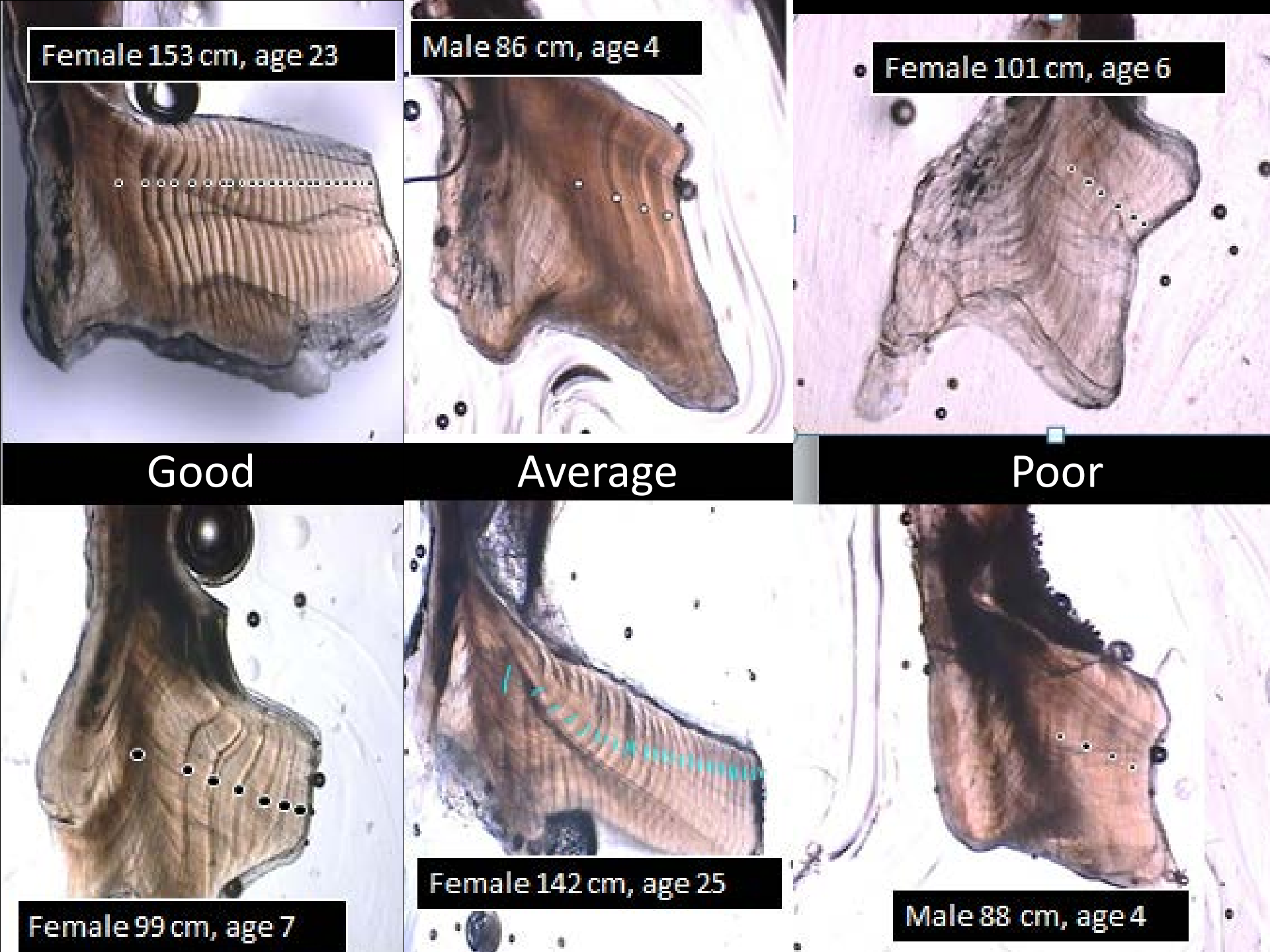
This section from a 21 year old 118 cm female king mackerel is a good example of how the first annulus can be fairly faint on the dorsal end while quite obvious on the ventral end of the otolith, although all subsequent annuli are much clearer on the dorsal end.

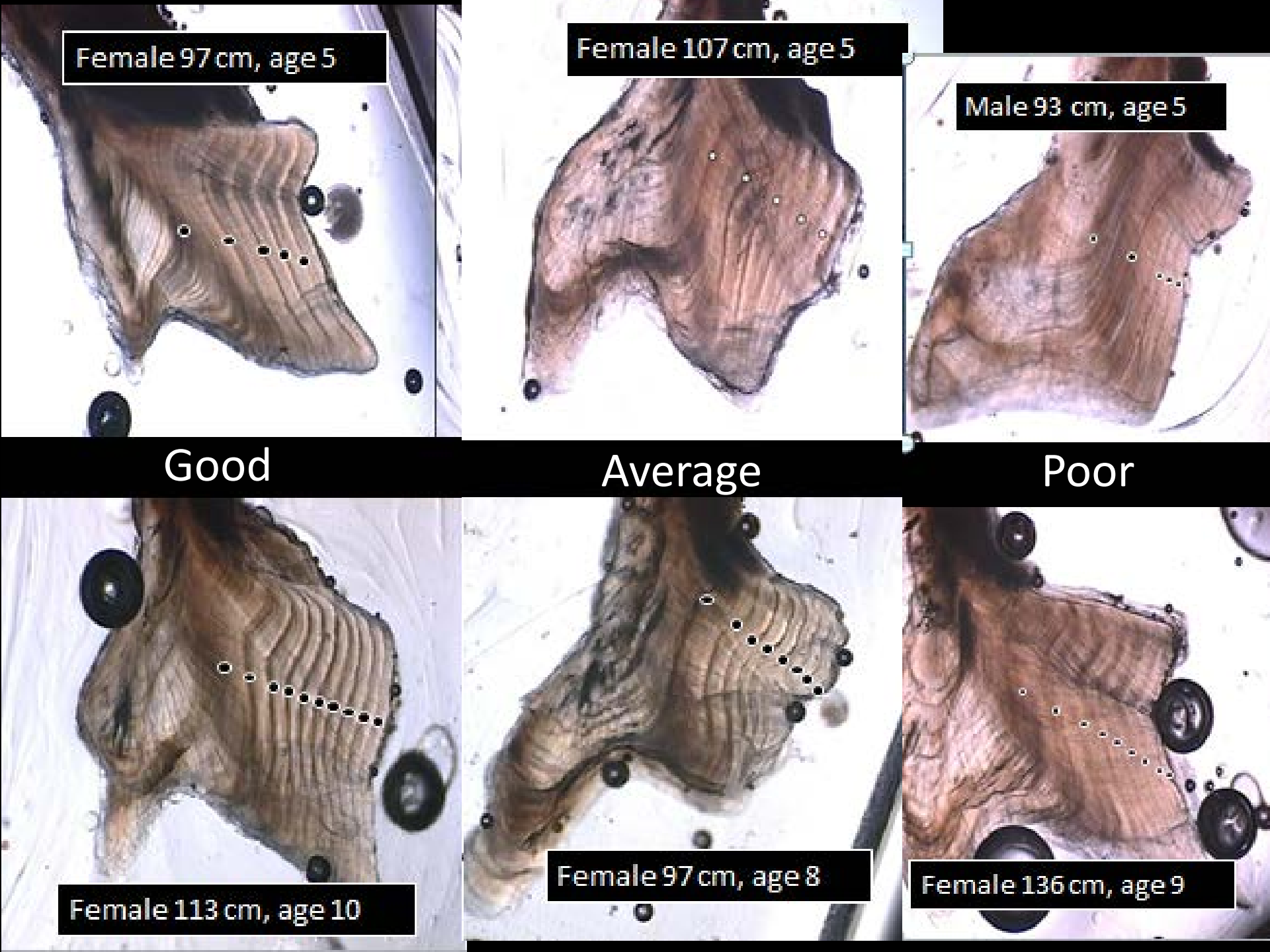


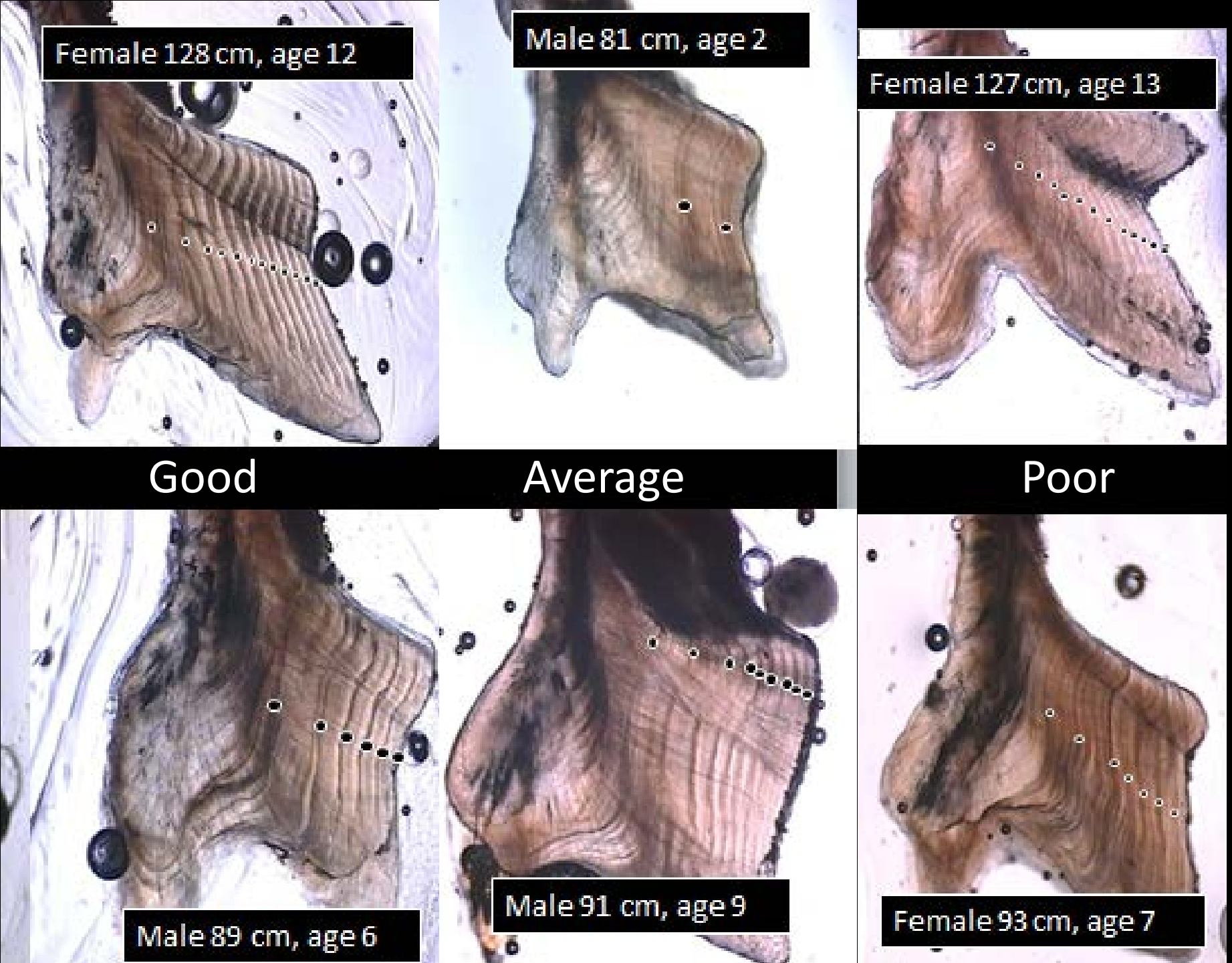
Assigning Readability Code

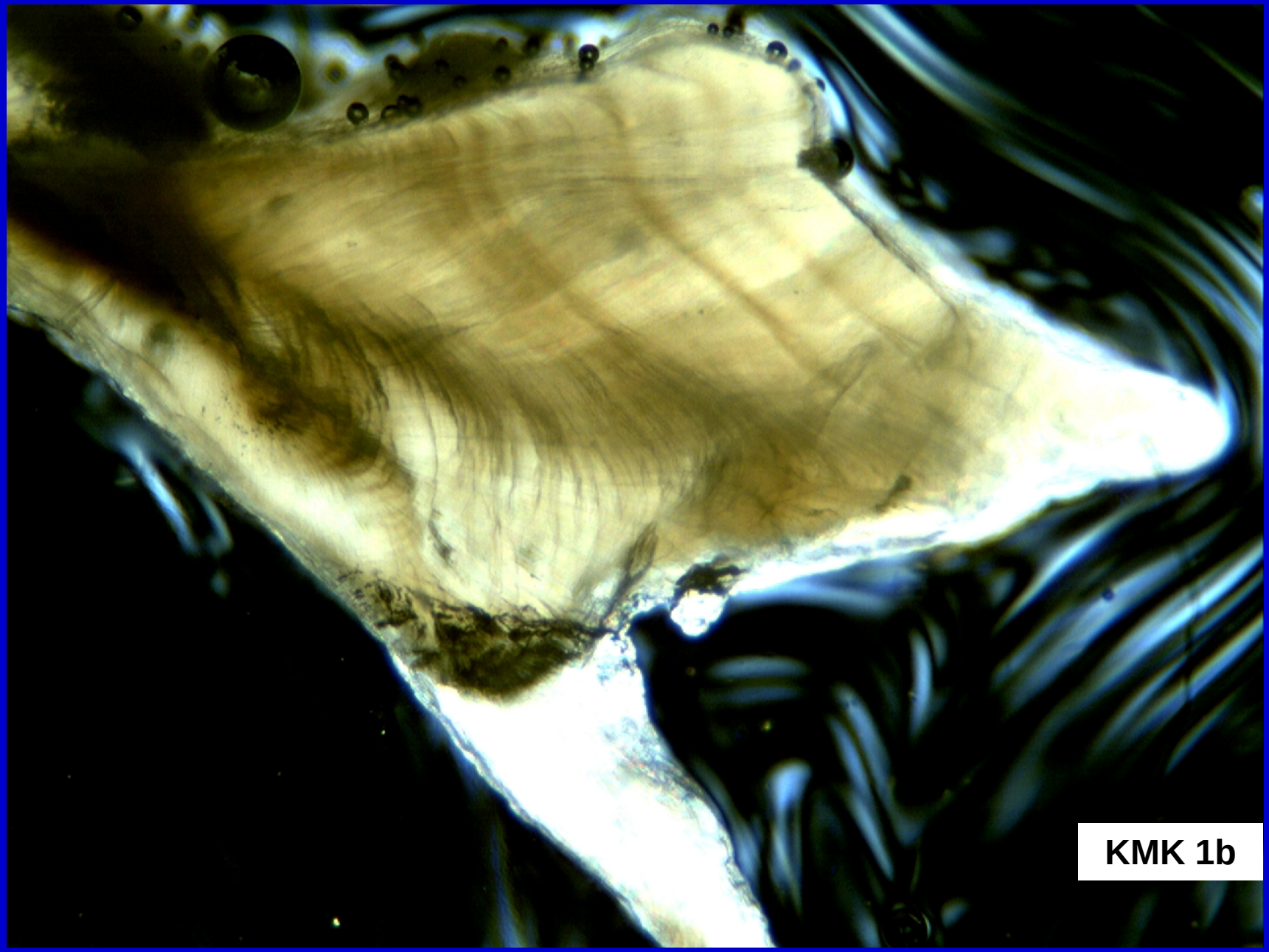
The following slides contain examples of sections that have been assigned a readability code. Readability codes are useful when comparing one reader's ages to another (i.e. easy to read sections should have higher agreement than difficult to read sections).

Codes are:
"G" for good/easy to read,
A" for average/fair to read
"P" for poor/difficult to read.


Female 153 cm, age 23
Male 86 cm, age 4
Female 101 cm, age 6
Good
Average
Poor
Female 99 cm, age 7
Female 142 cm, age 25
Male 88 cm, age 4


Female 97 cm, age 5
Female 107 cm, age 5
Male 93 cm, age 5
Good
Average
Poor
Female 113 cm, age 10
Female 97 cm, age 8
Female 136 cm, age 9


Female 128 cm, age 12
Male 81 cm, age 2
Female 127 cm, age 13
Good
Average
Poor
Male 89 cm, age 6
Male 91 cm, age 9
Female 93 cm, age 7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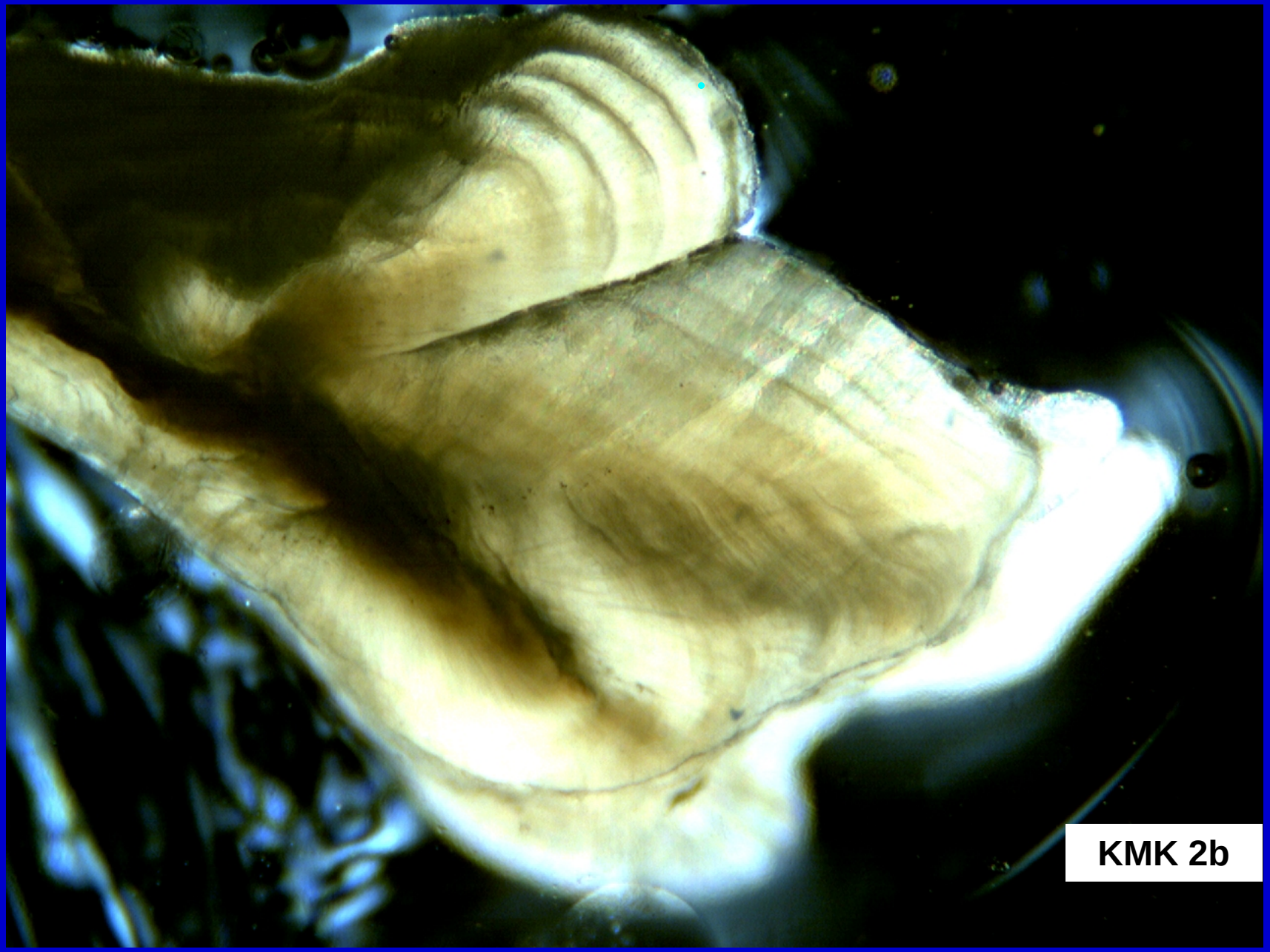
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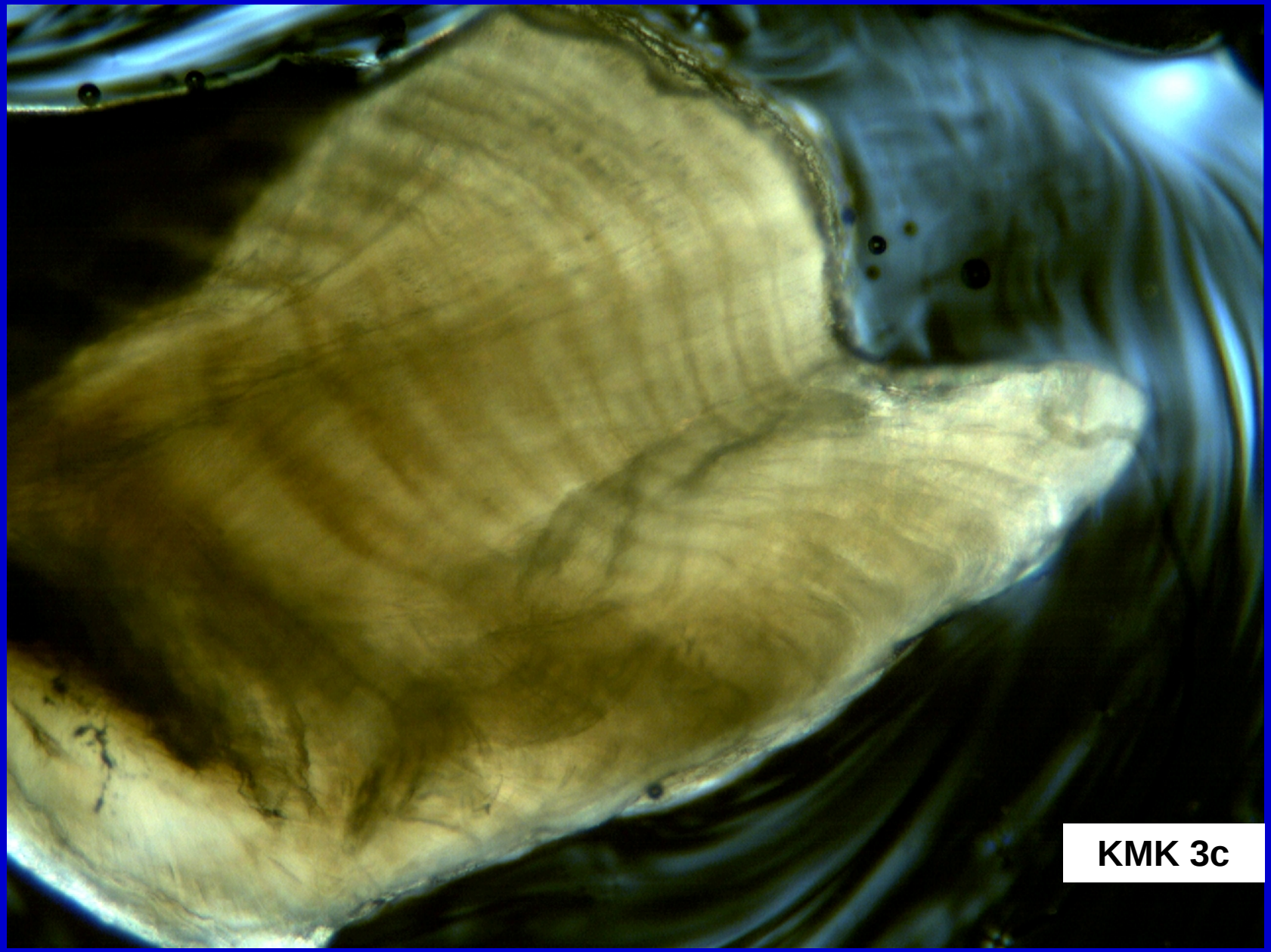
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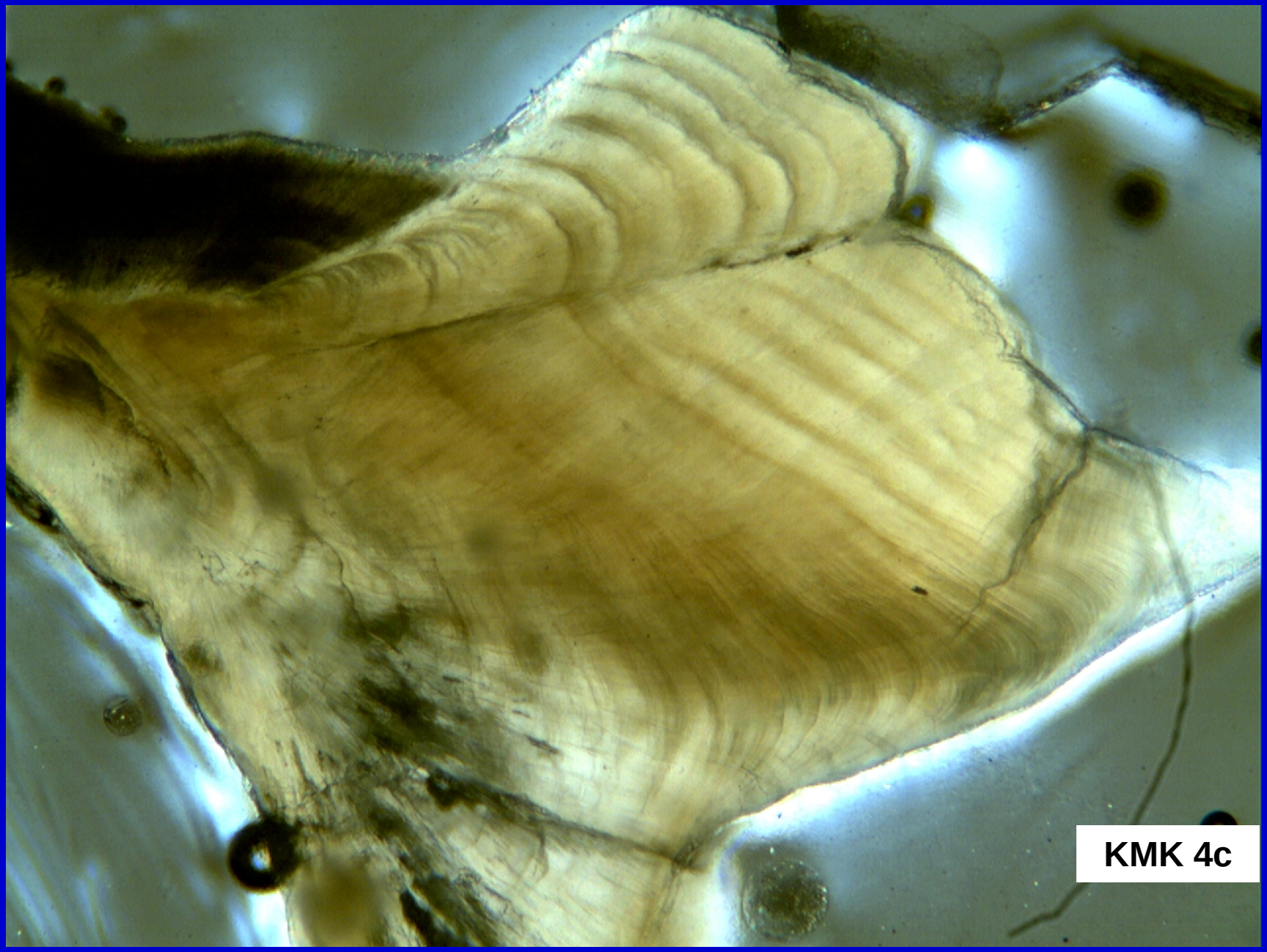
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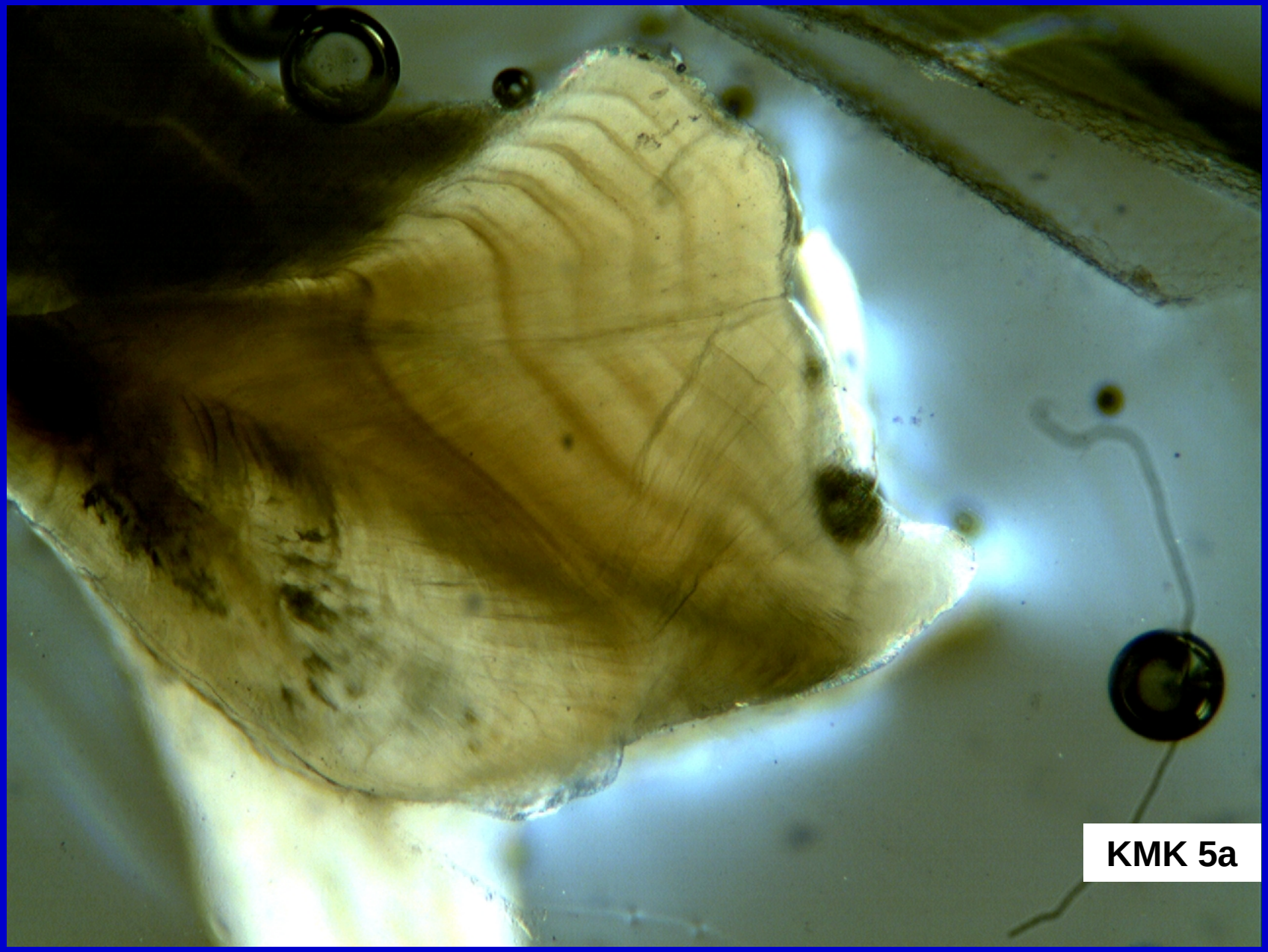
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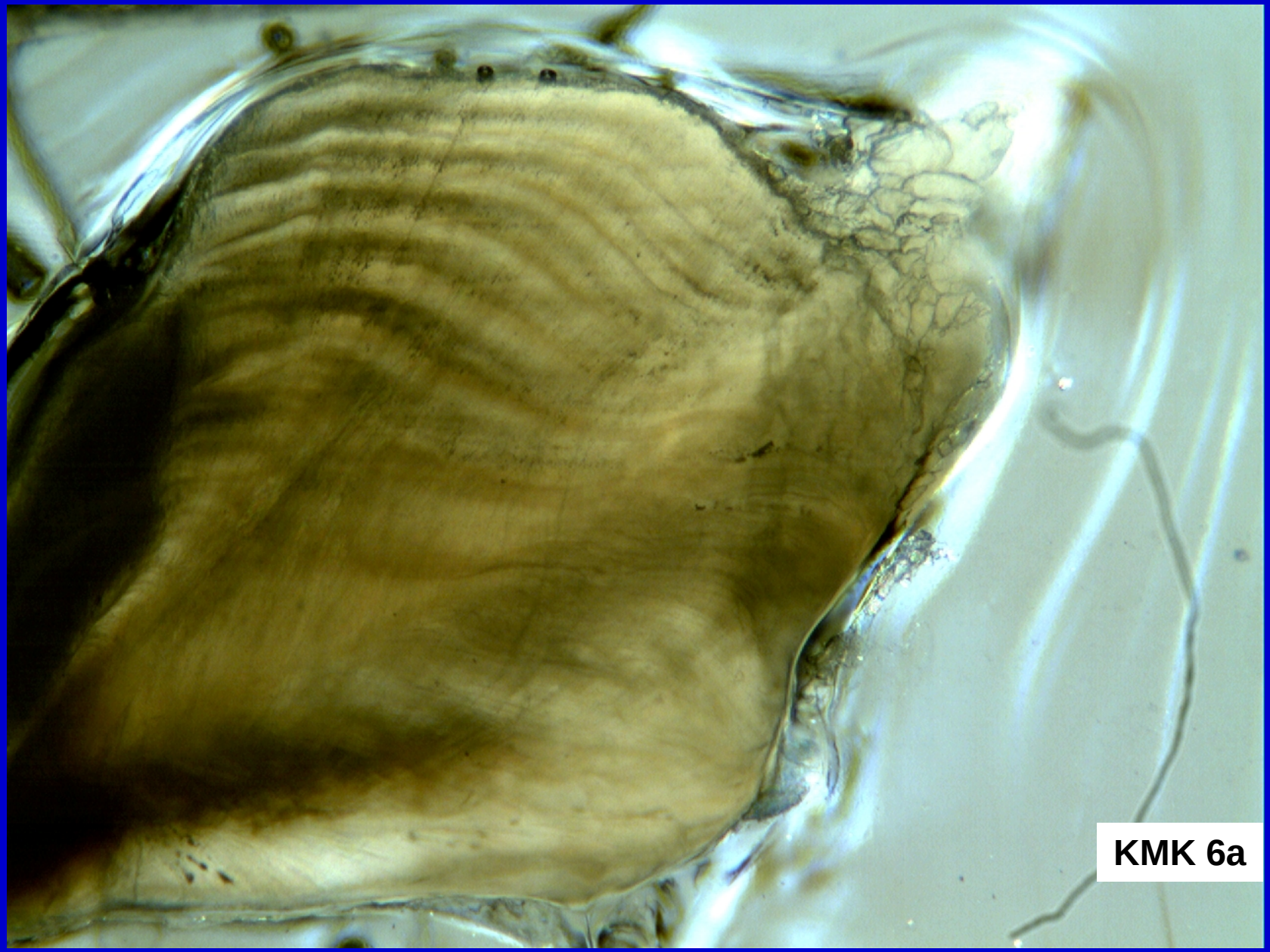
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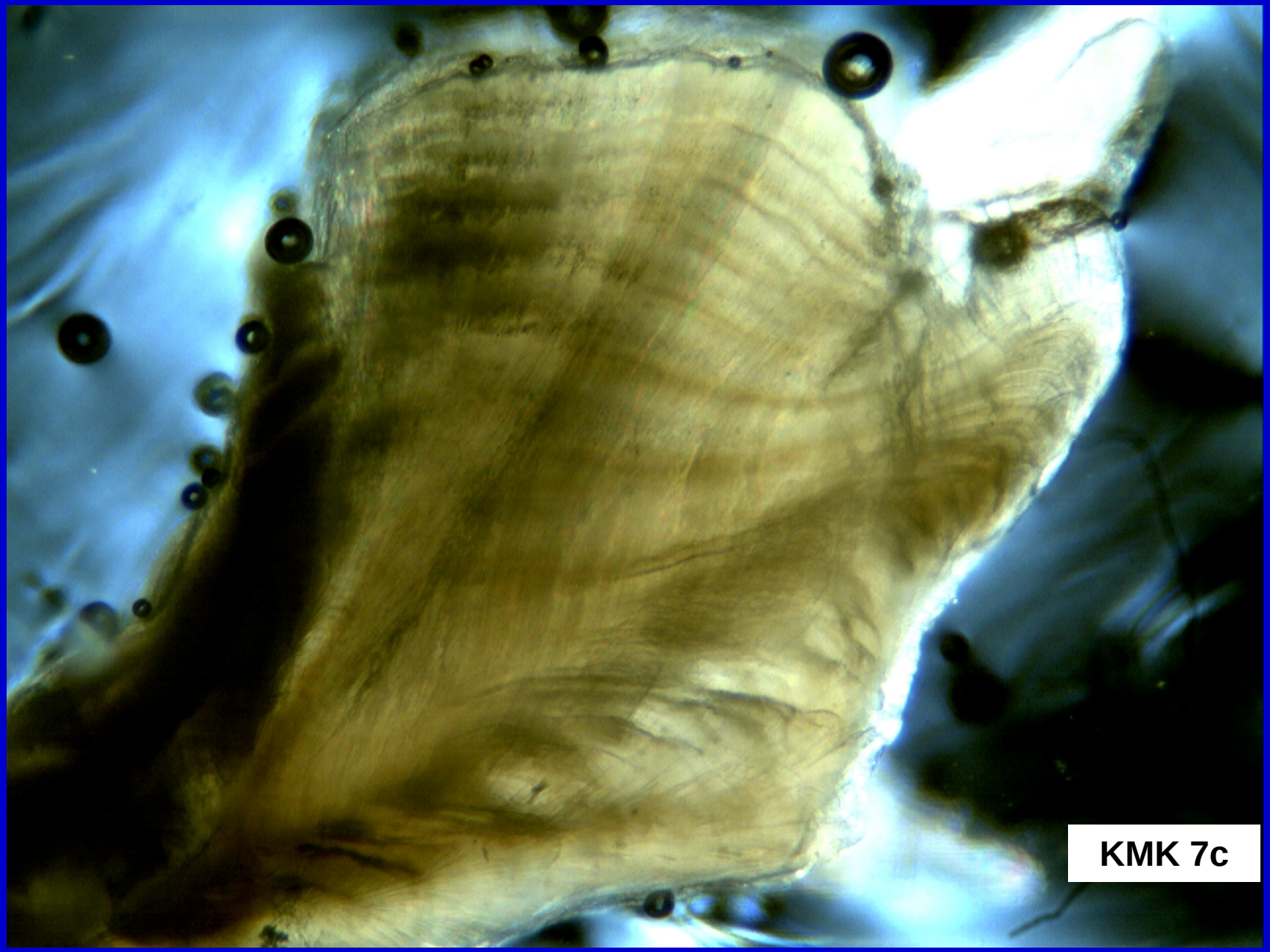
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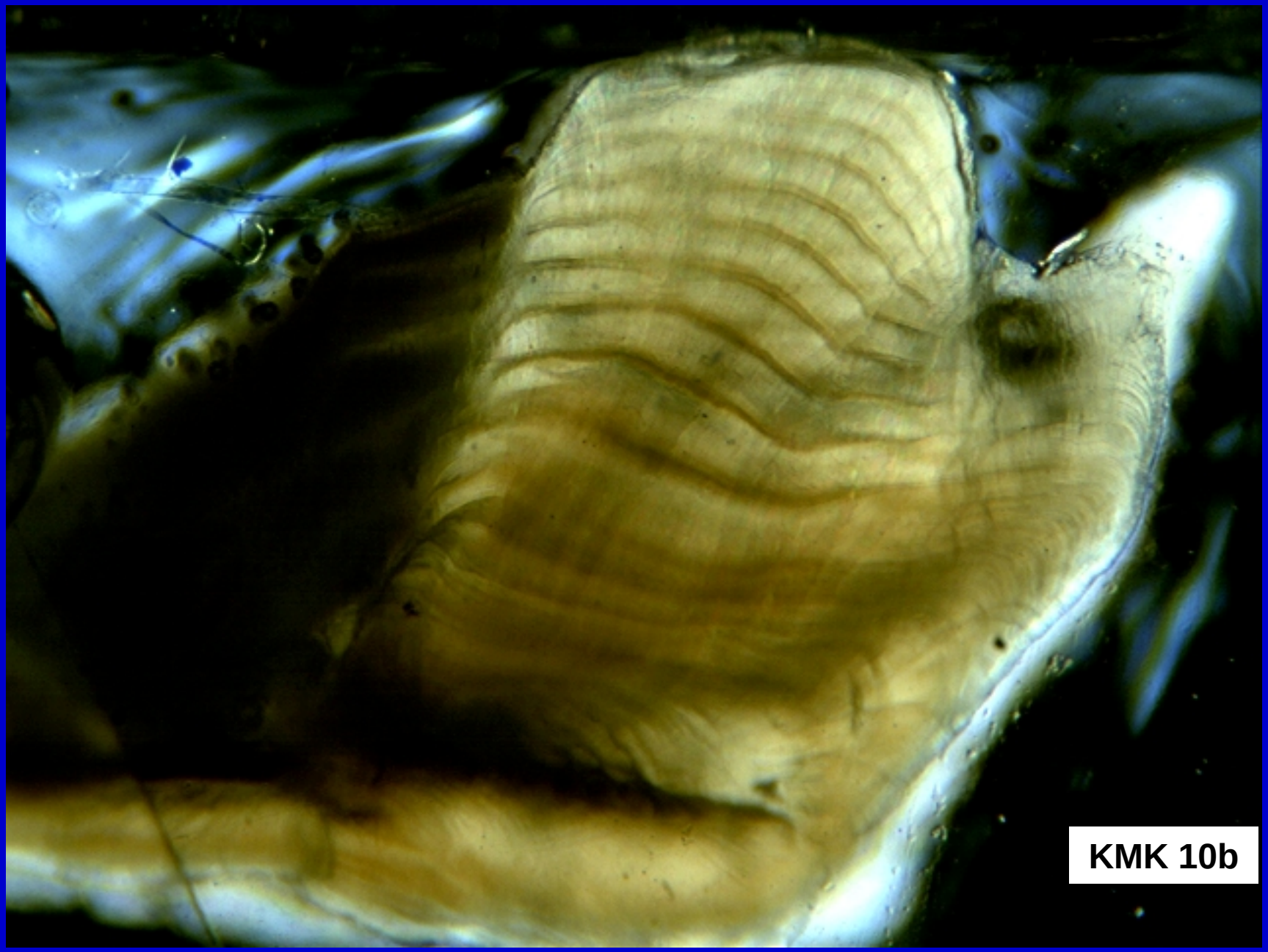
KMK 8a

KMK 9b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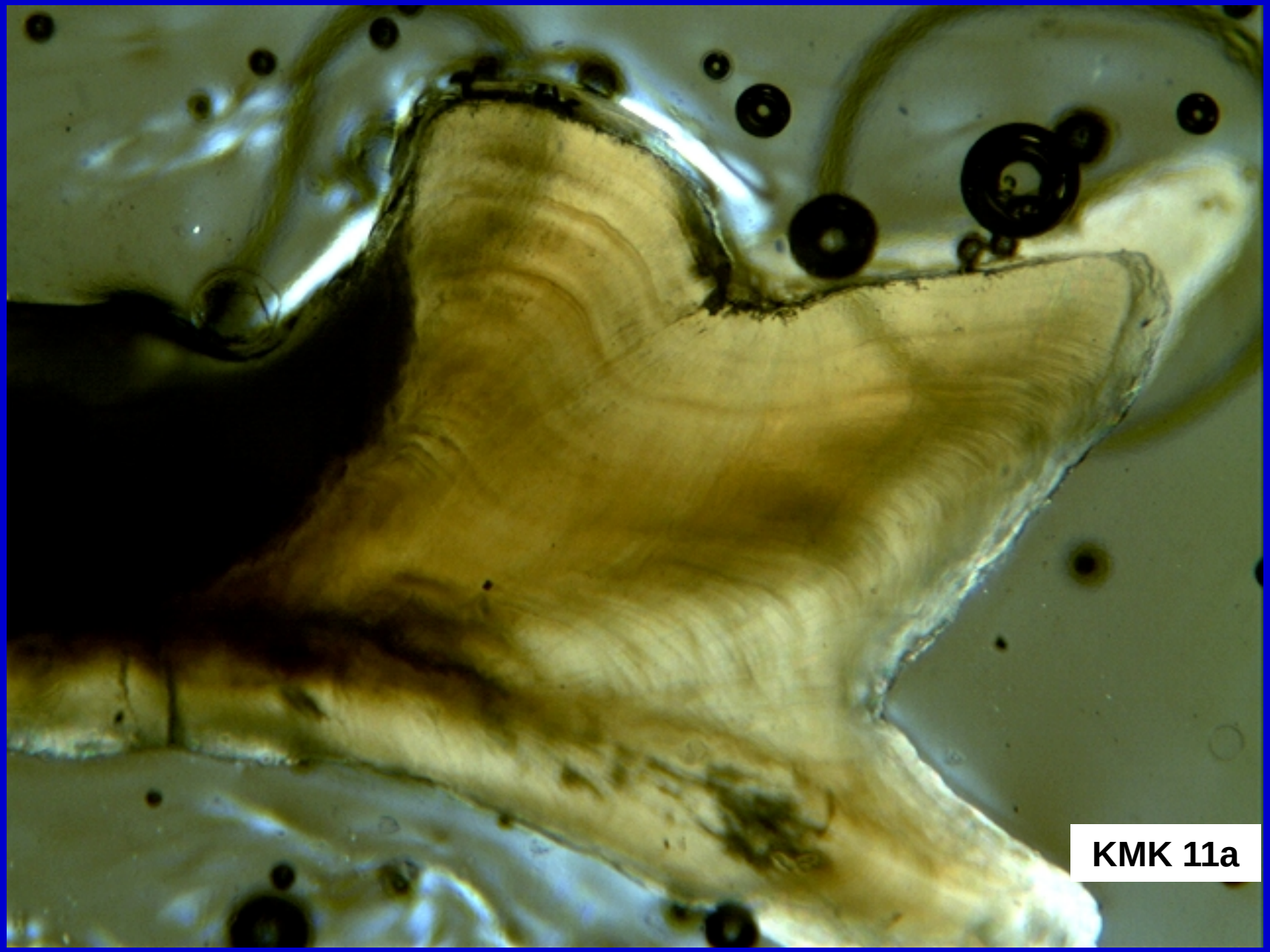
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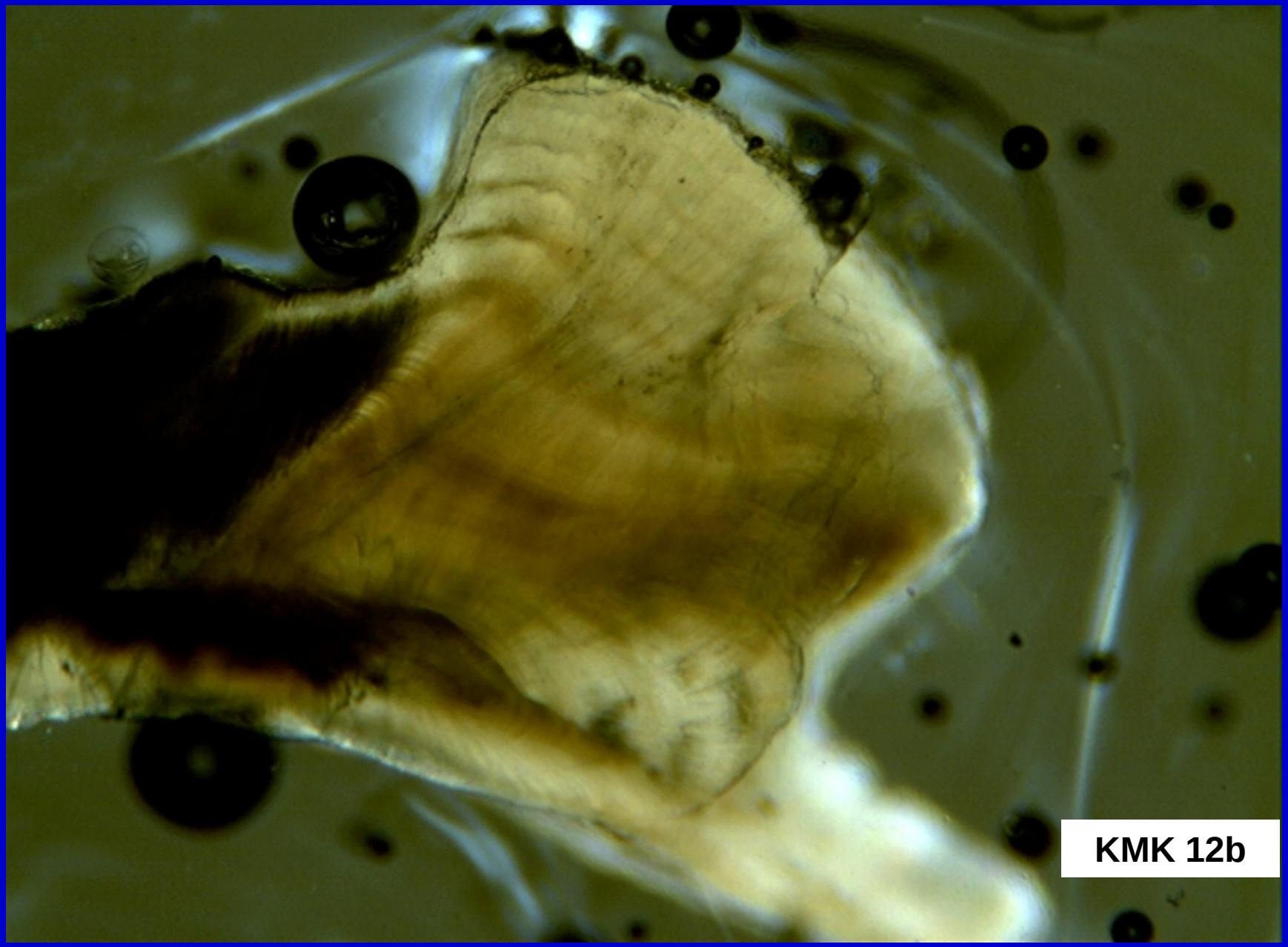
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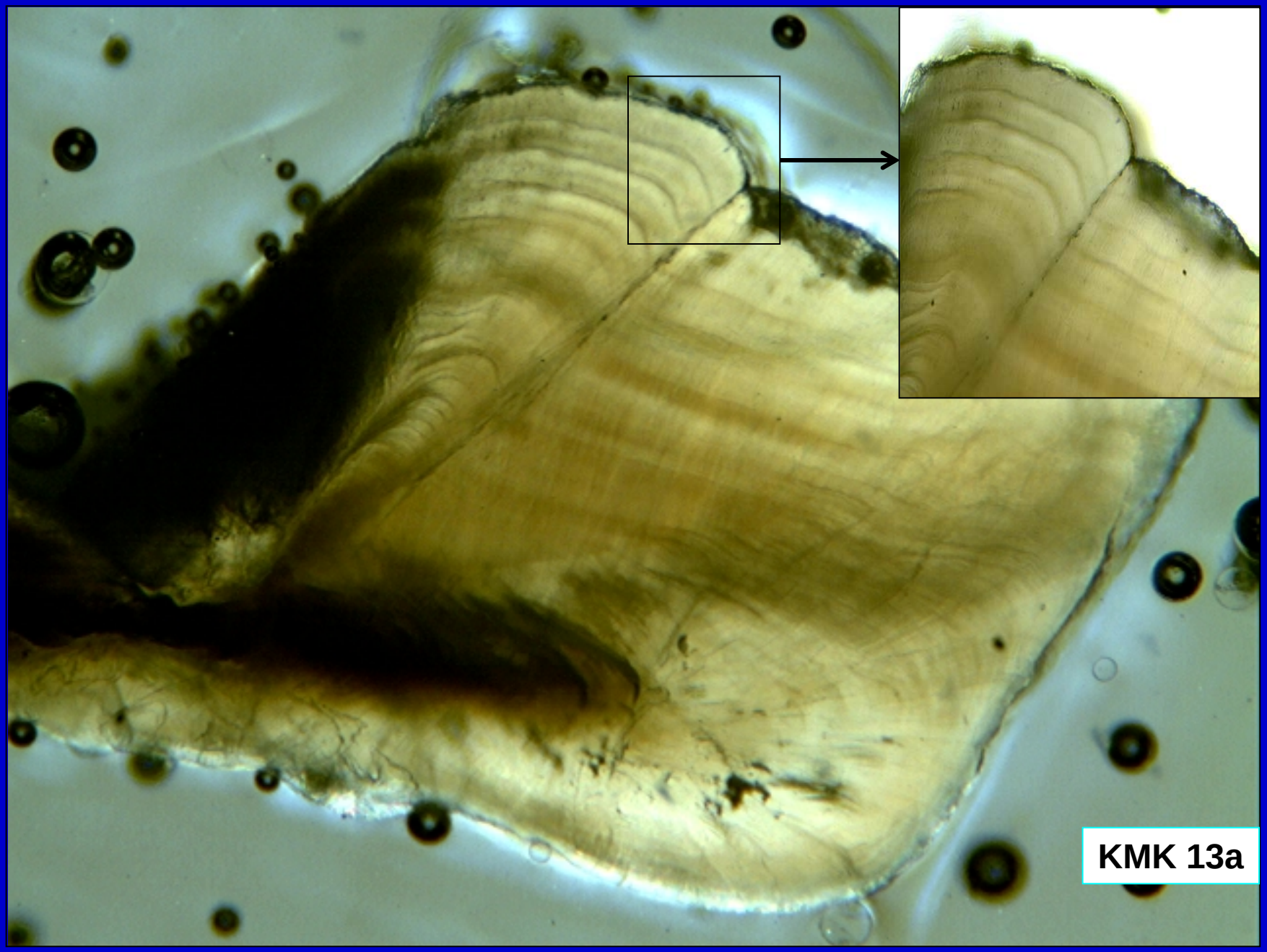
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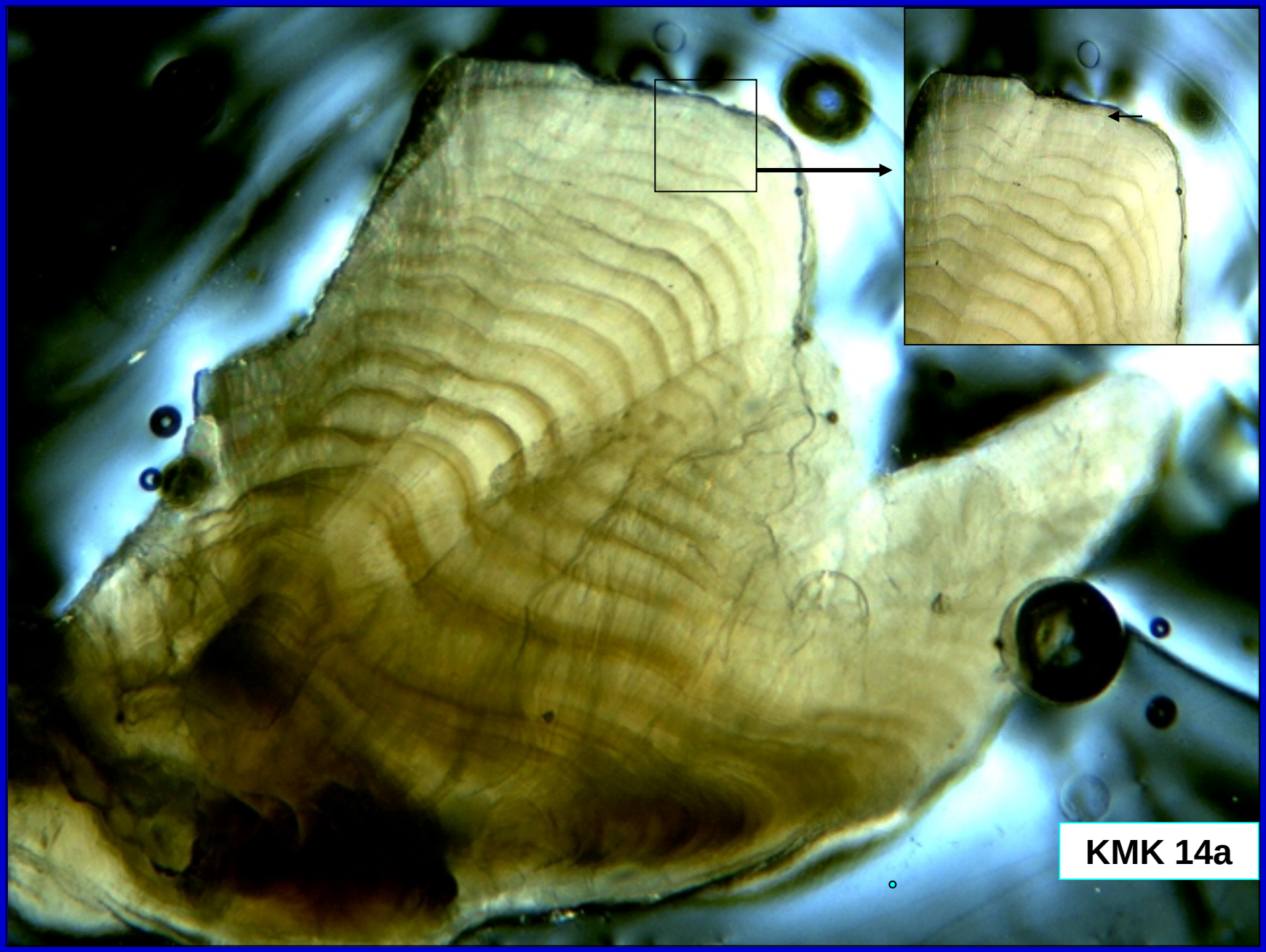
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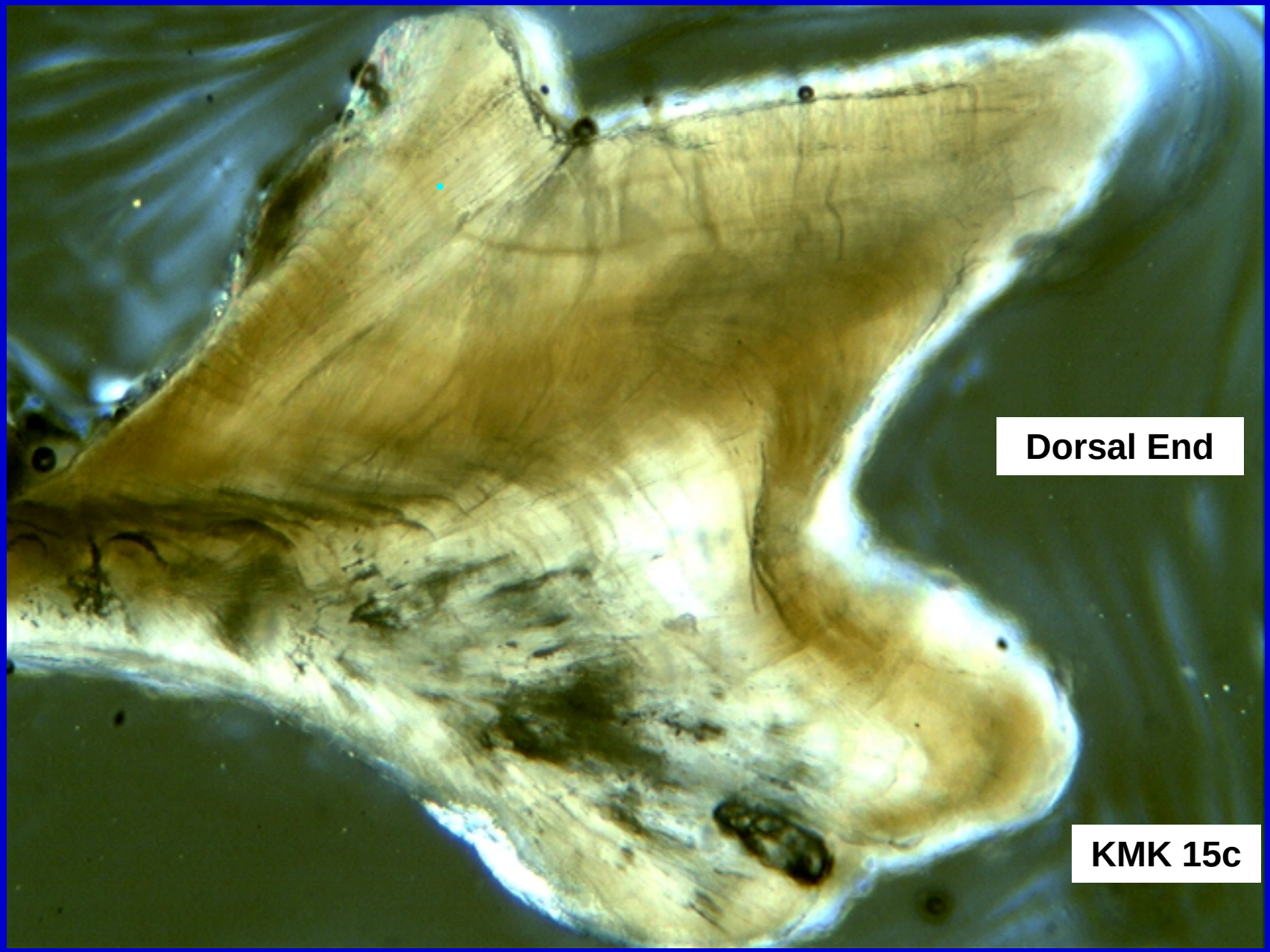
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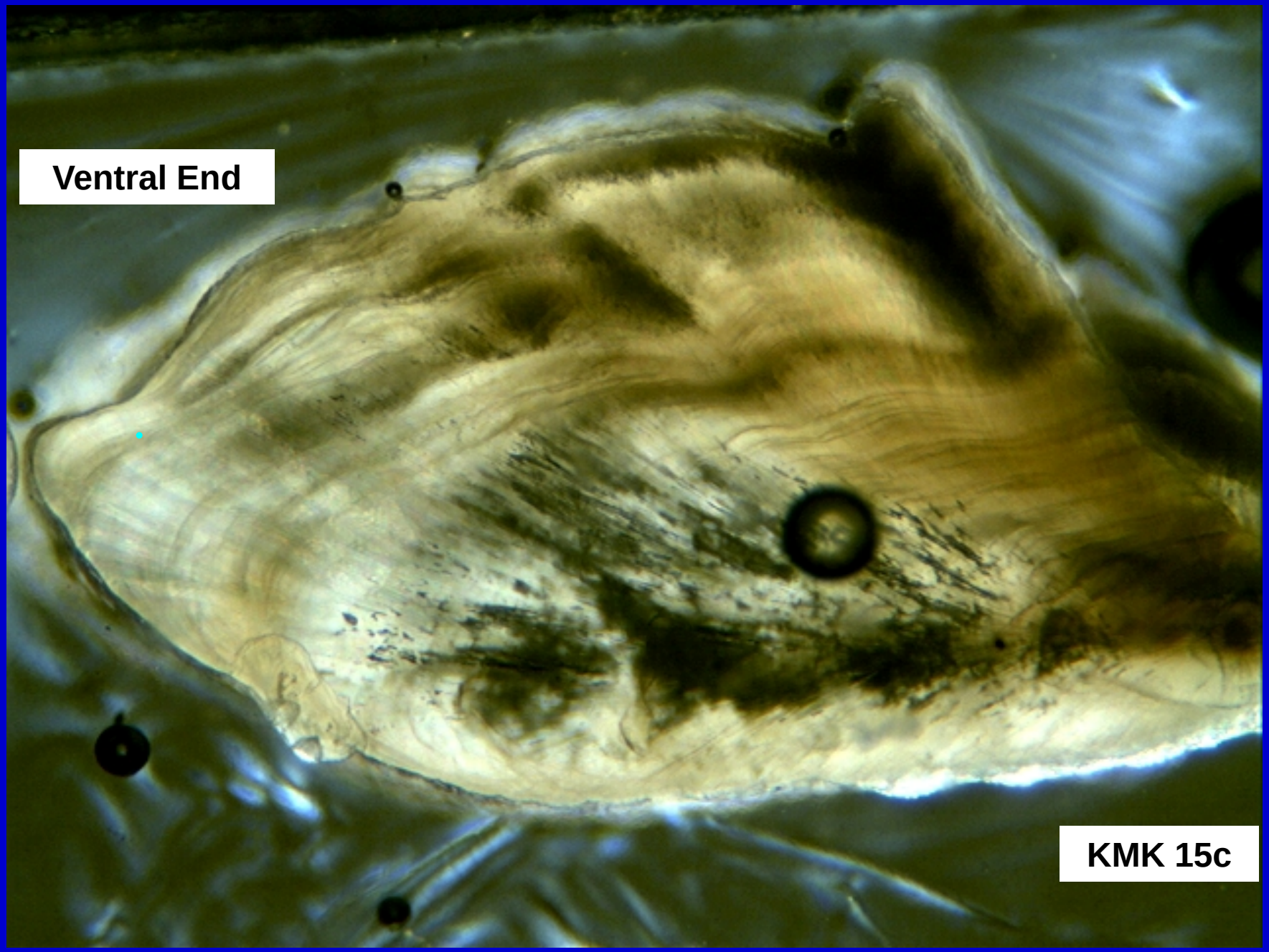
Ventral End
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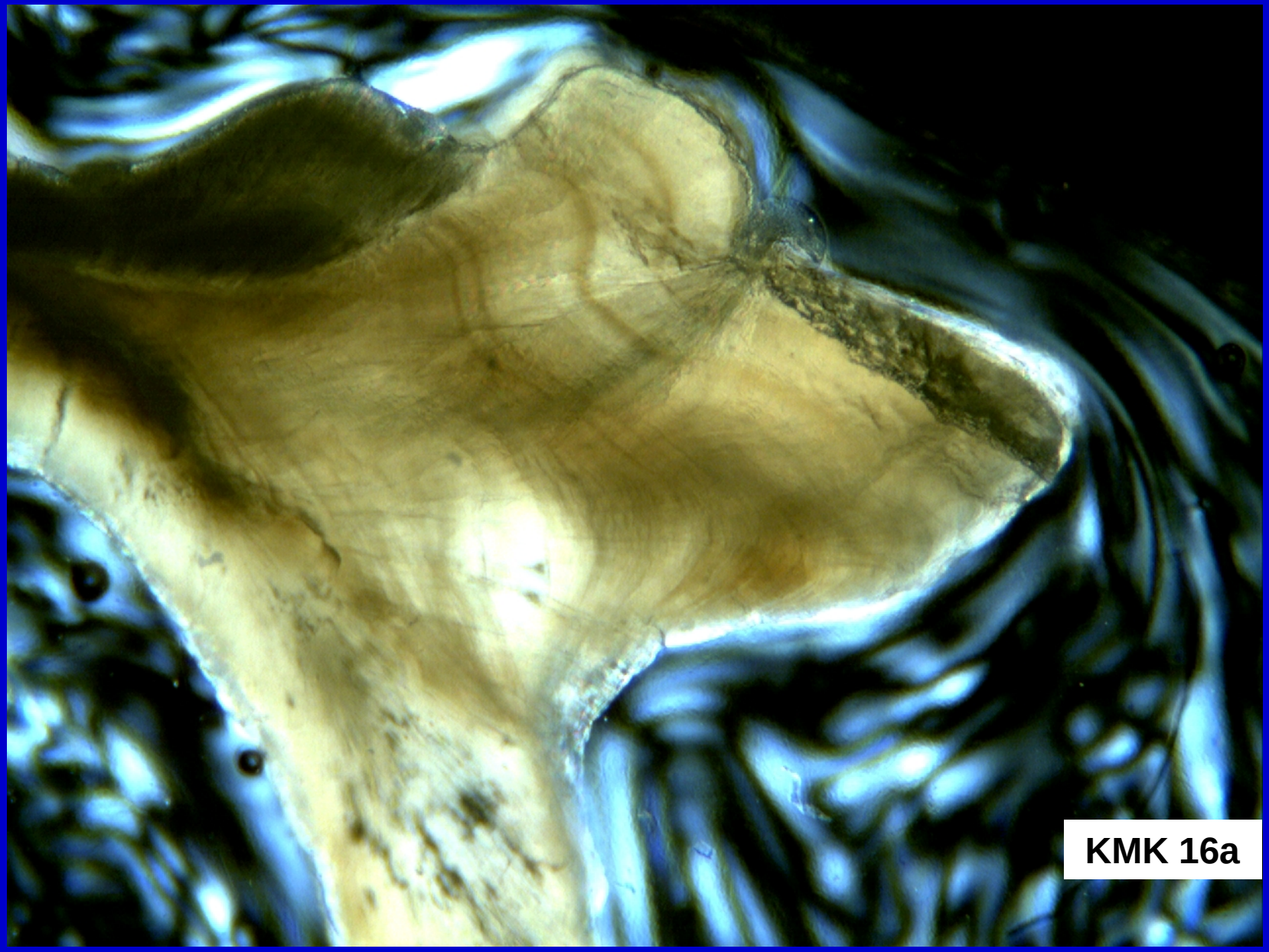
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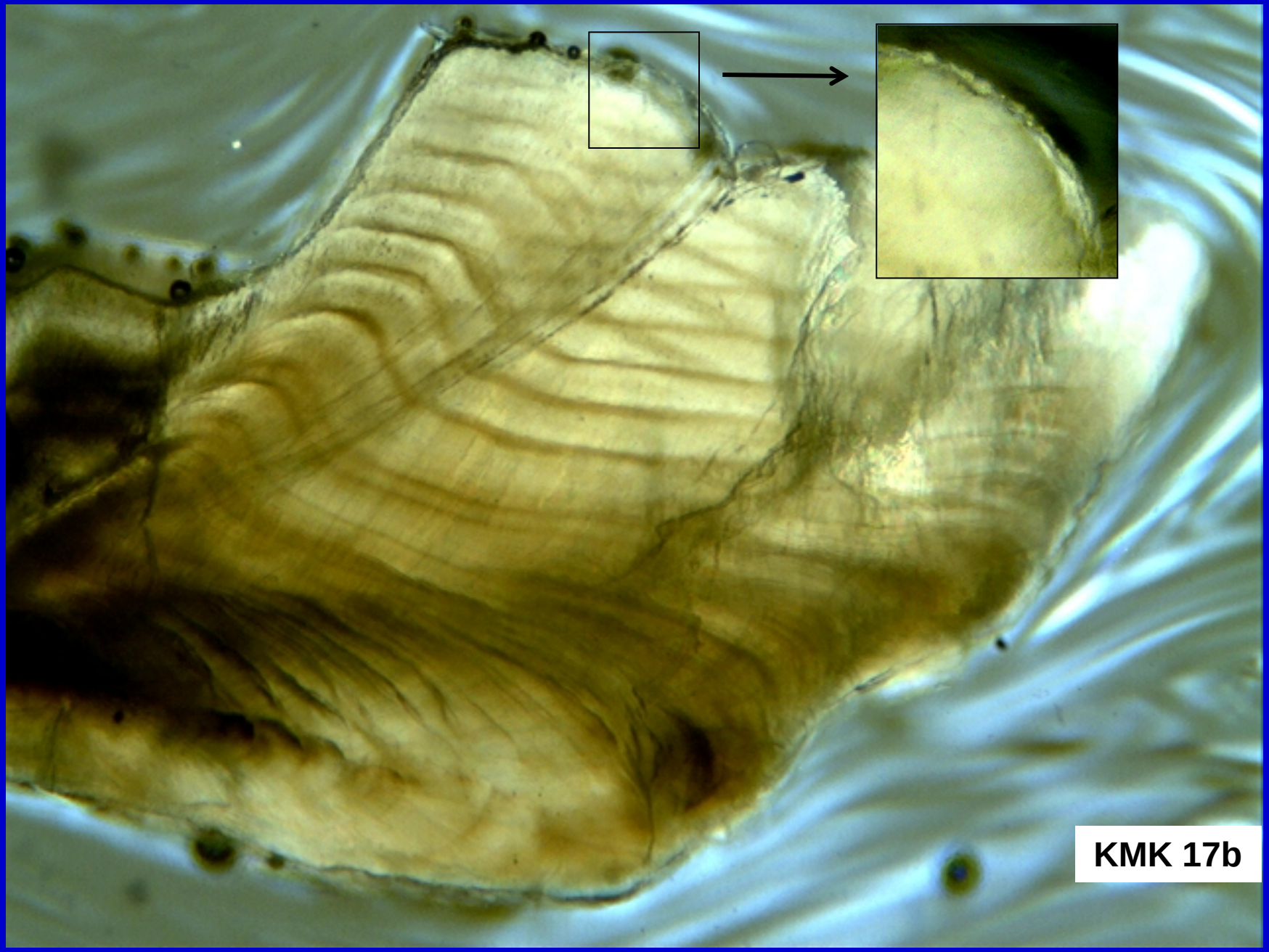
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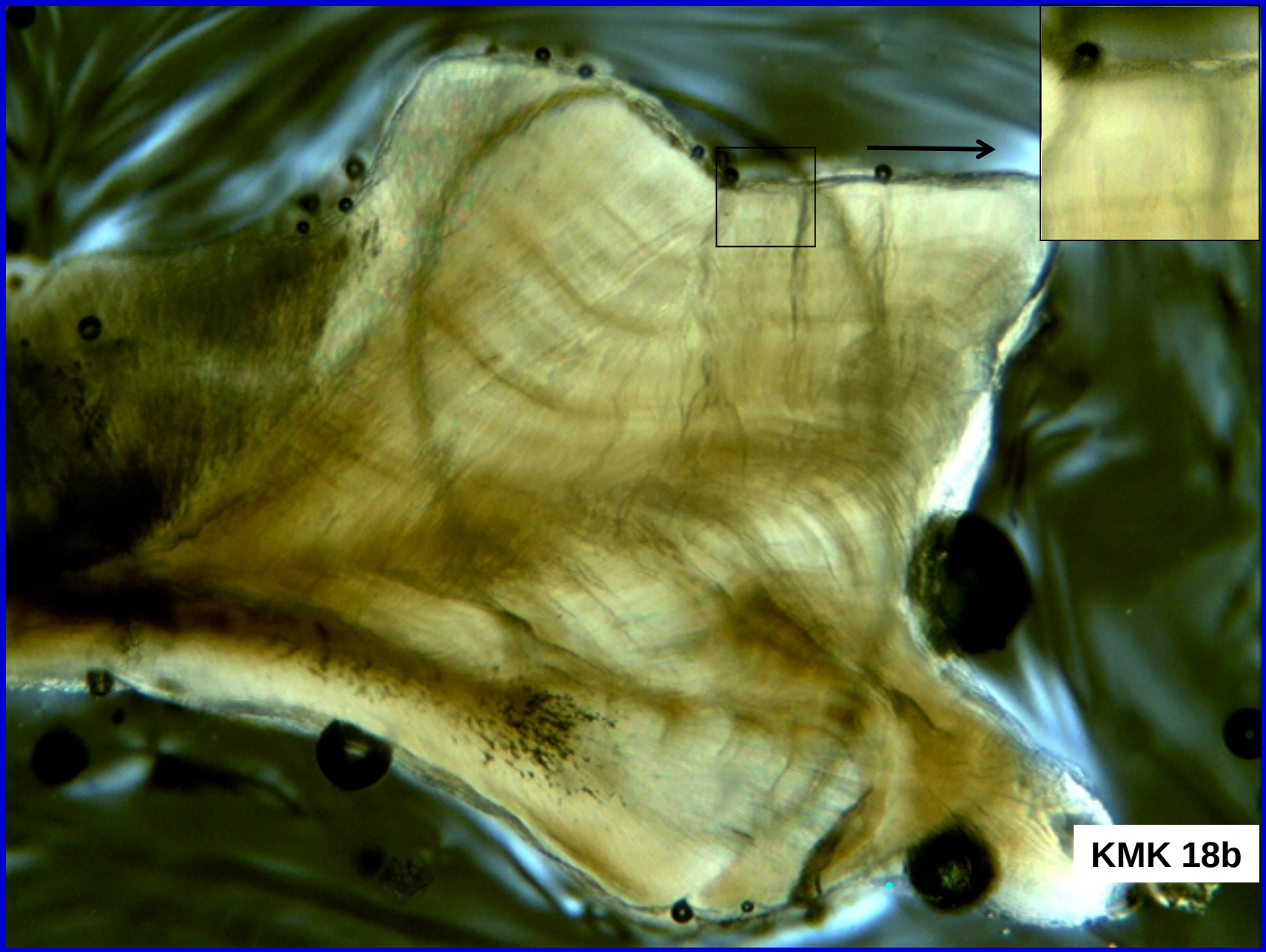
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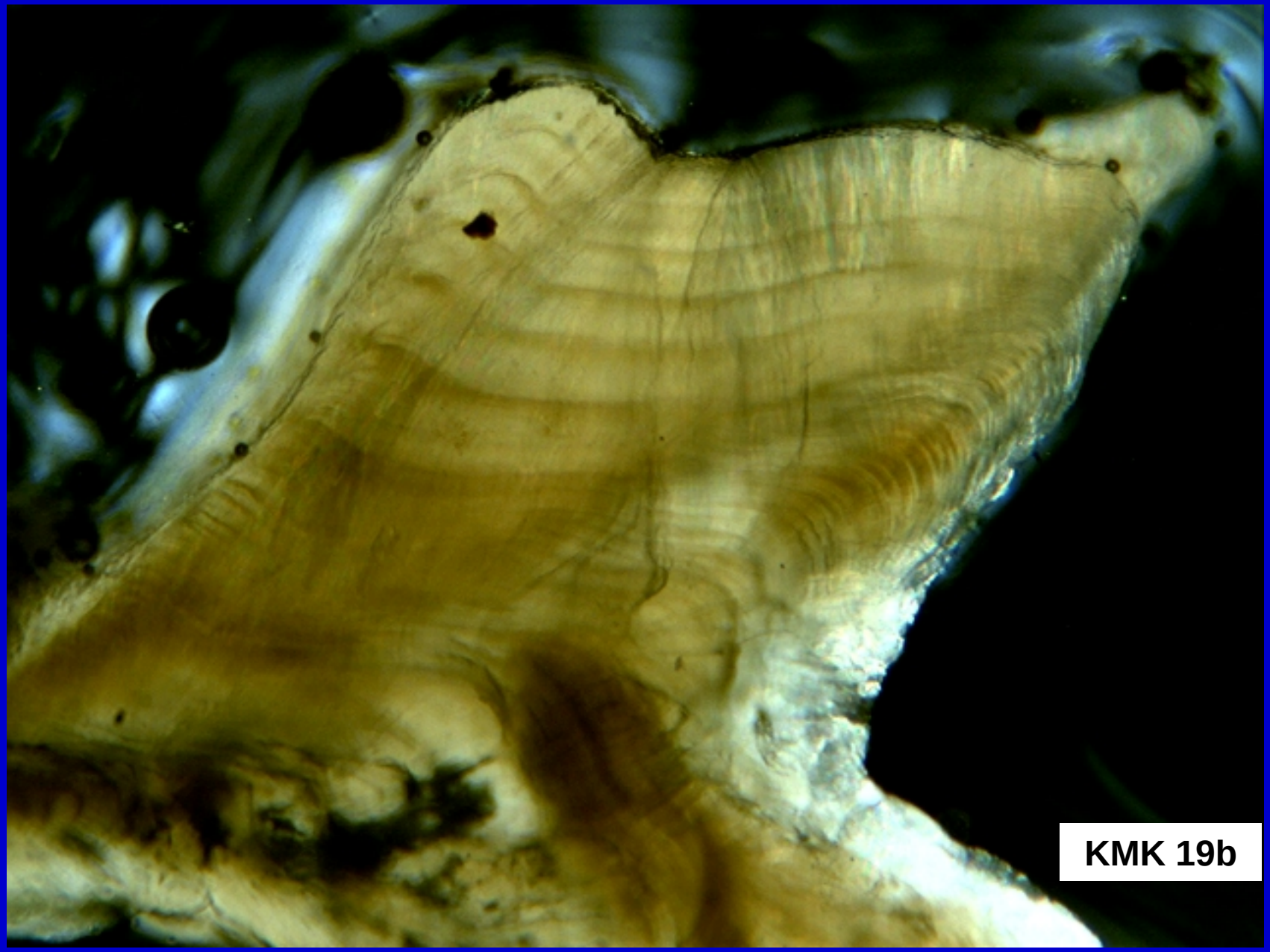
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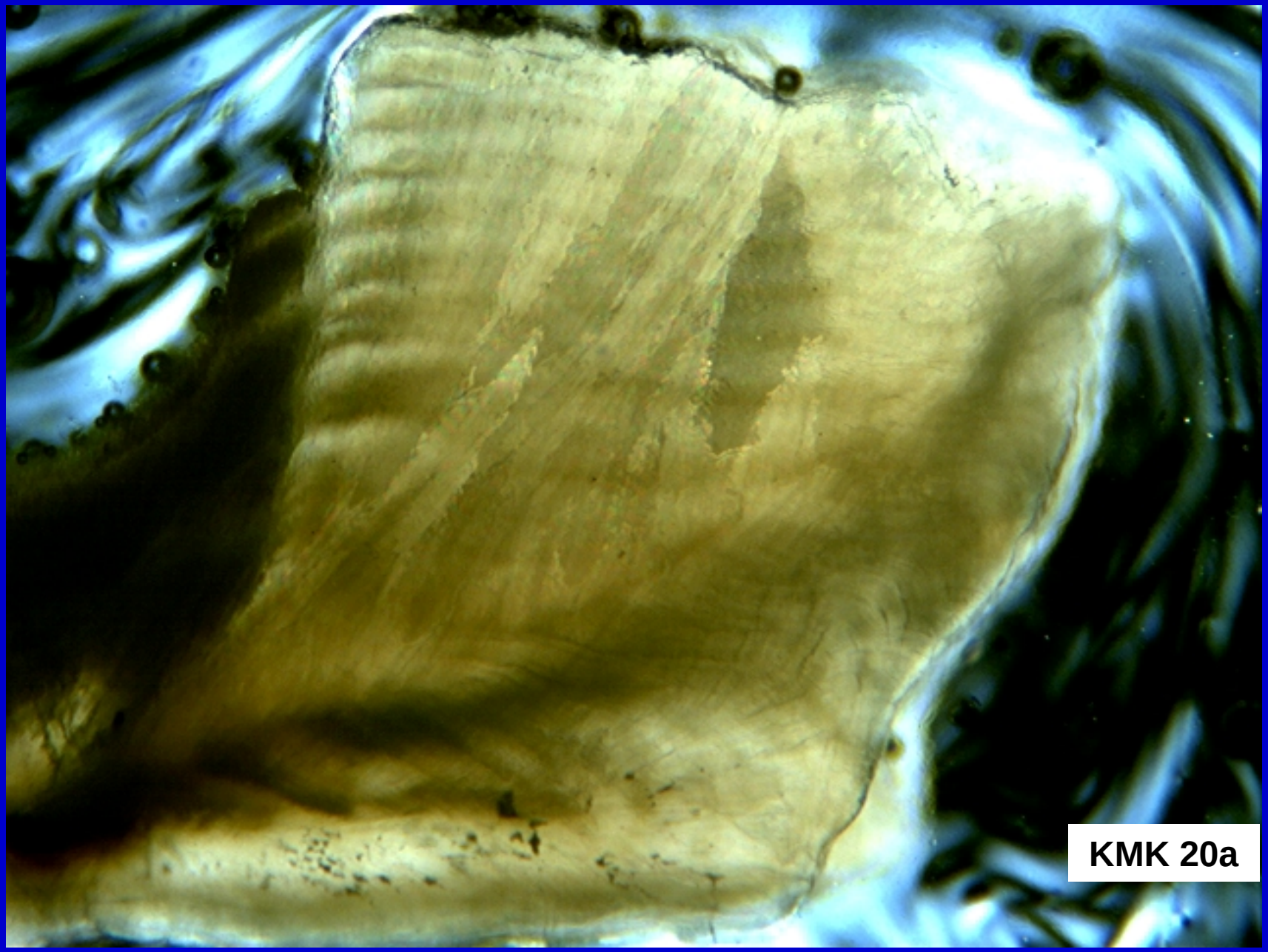
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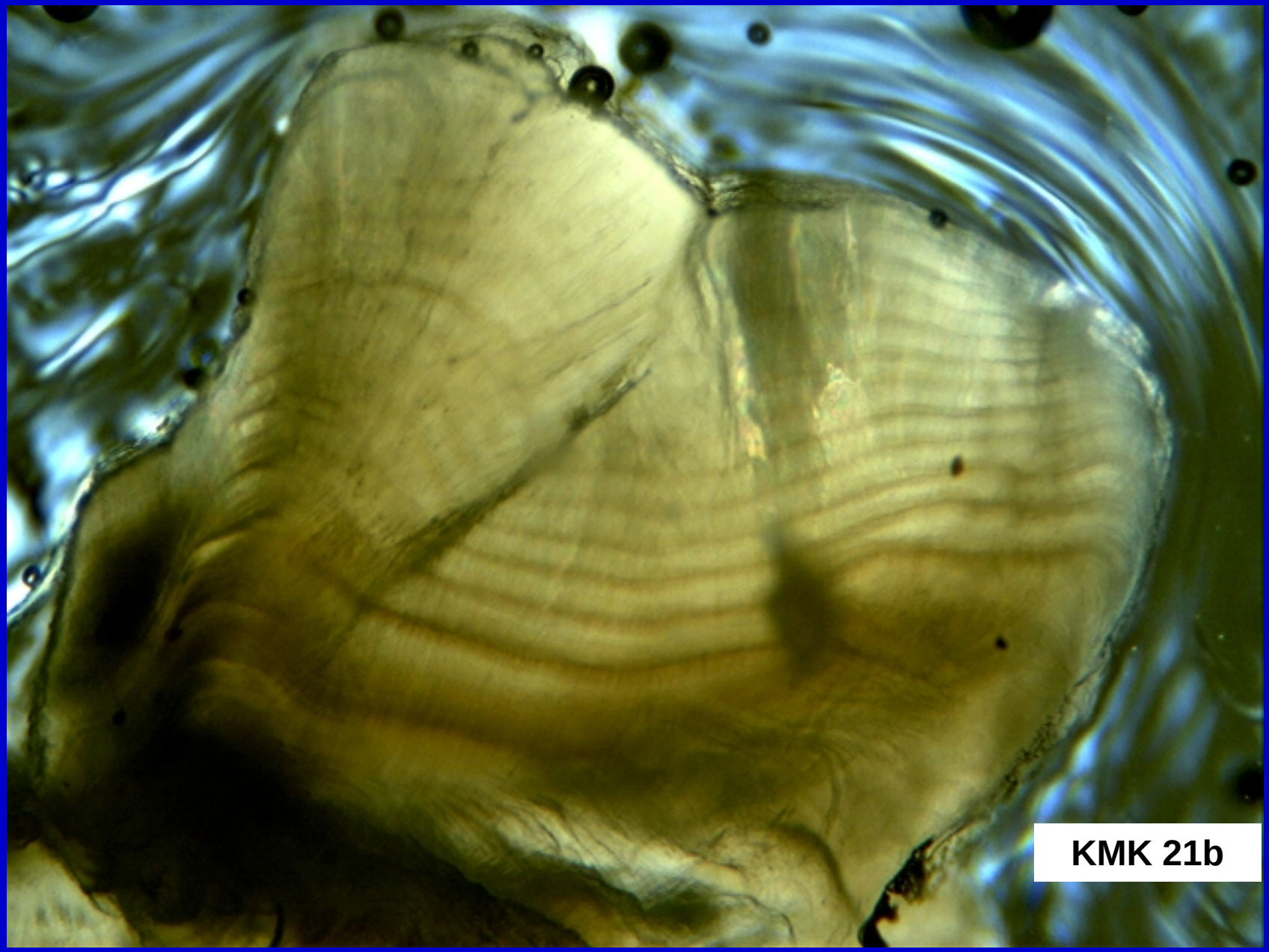
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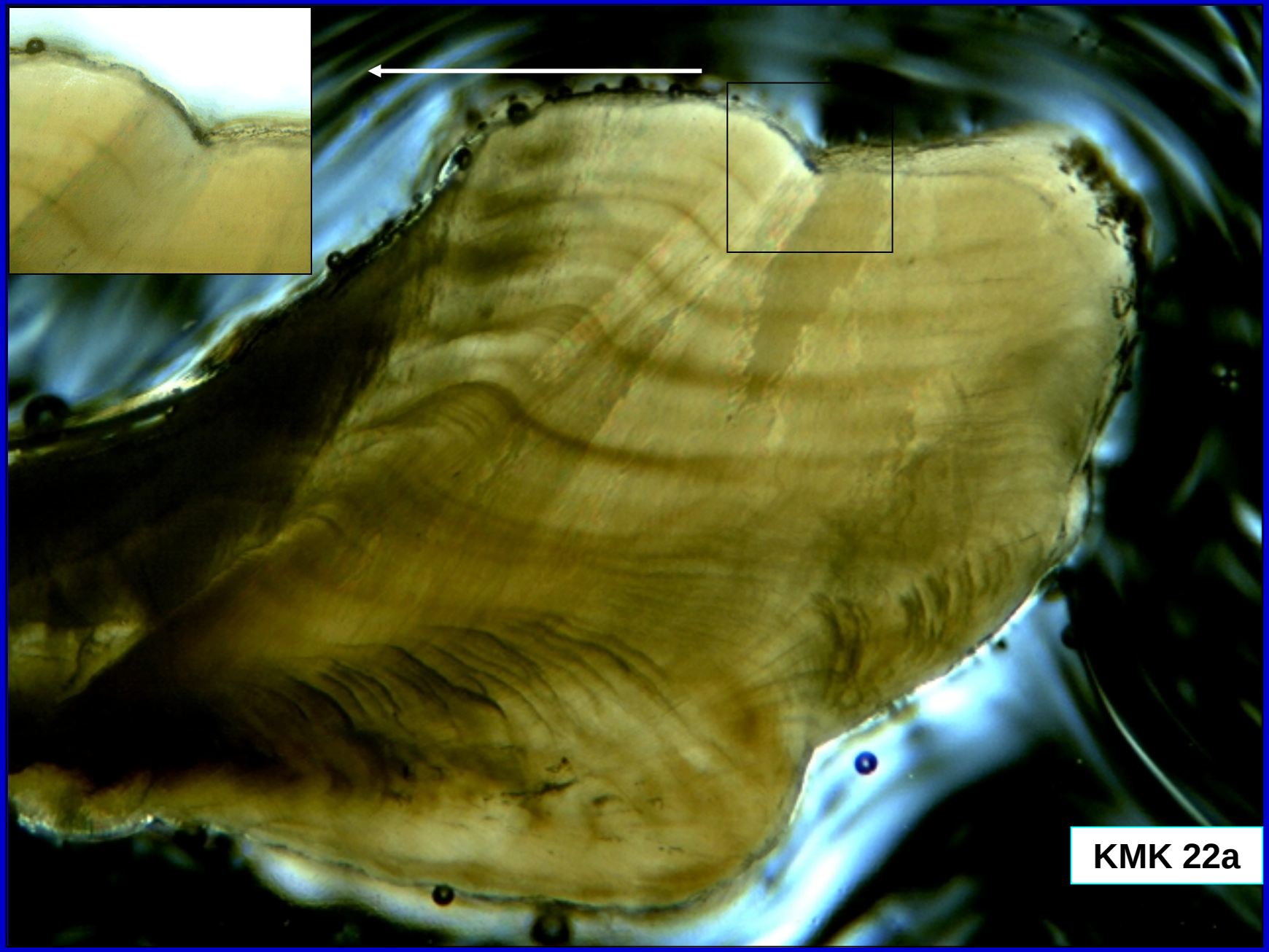
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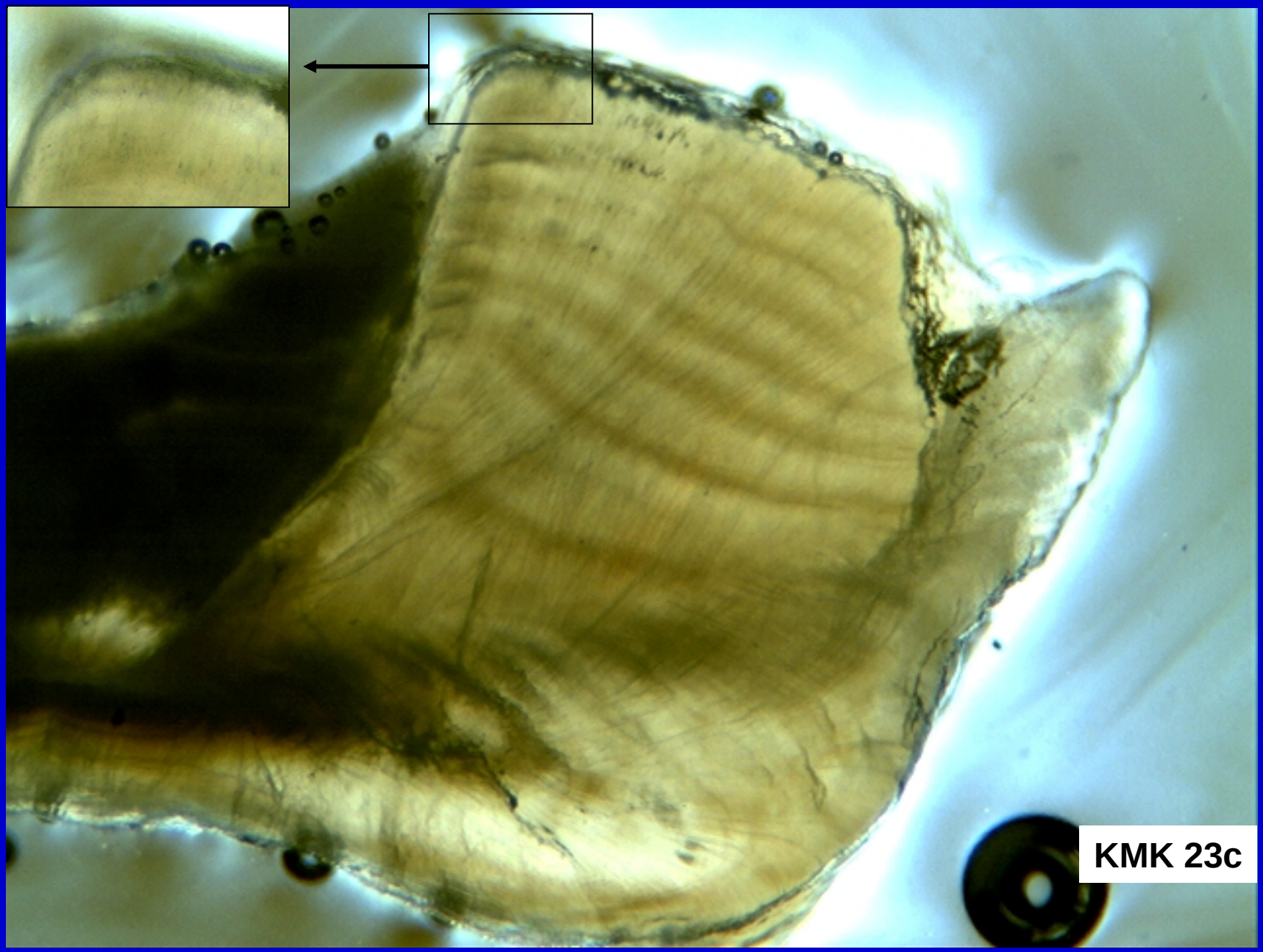
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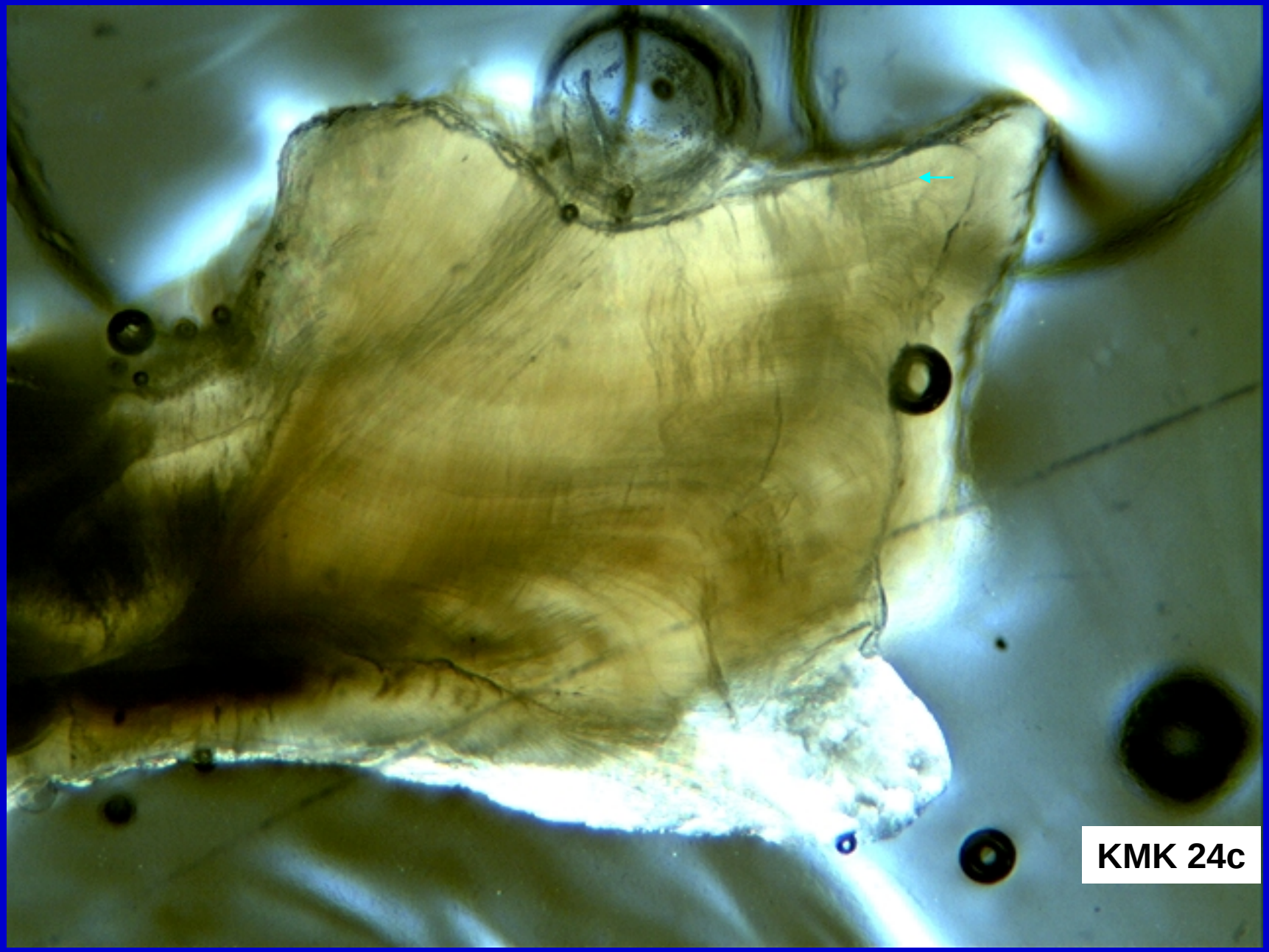
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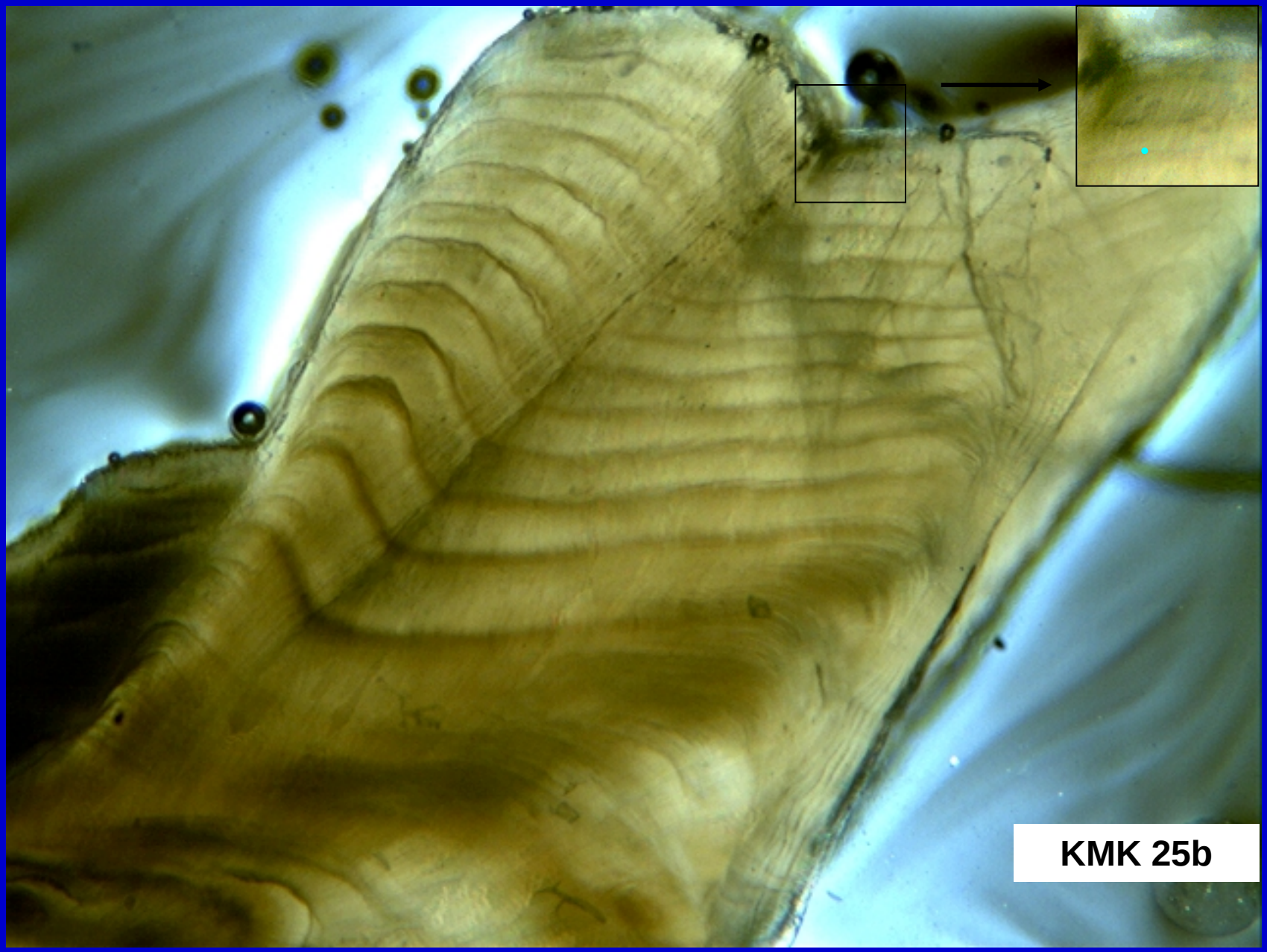
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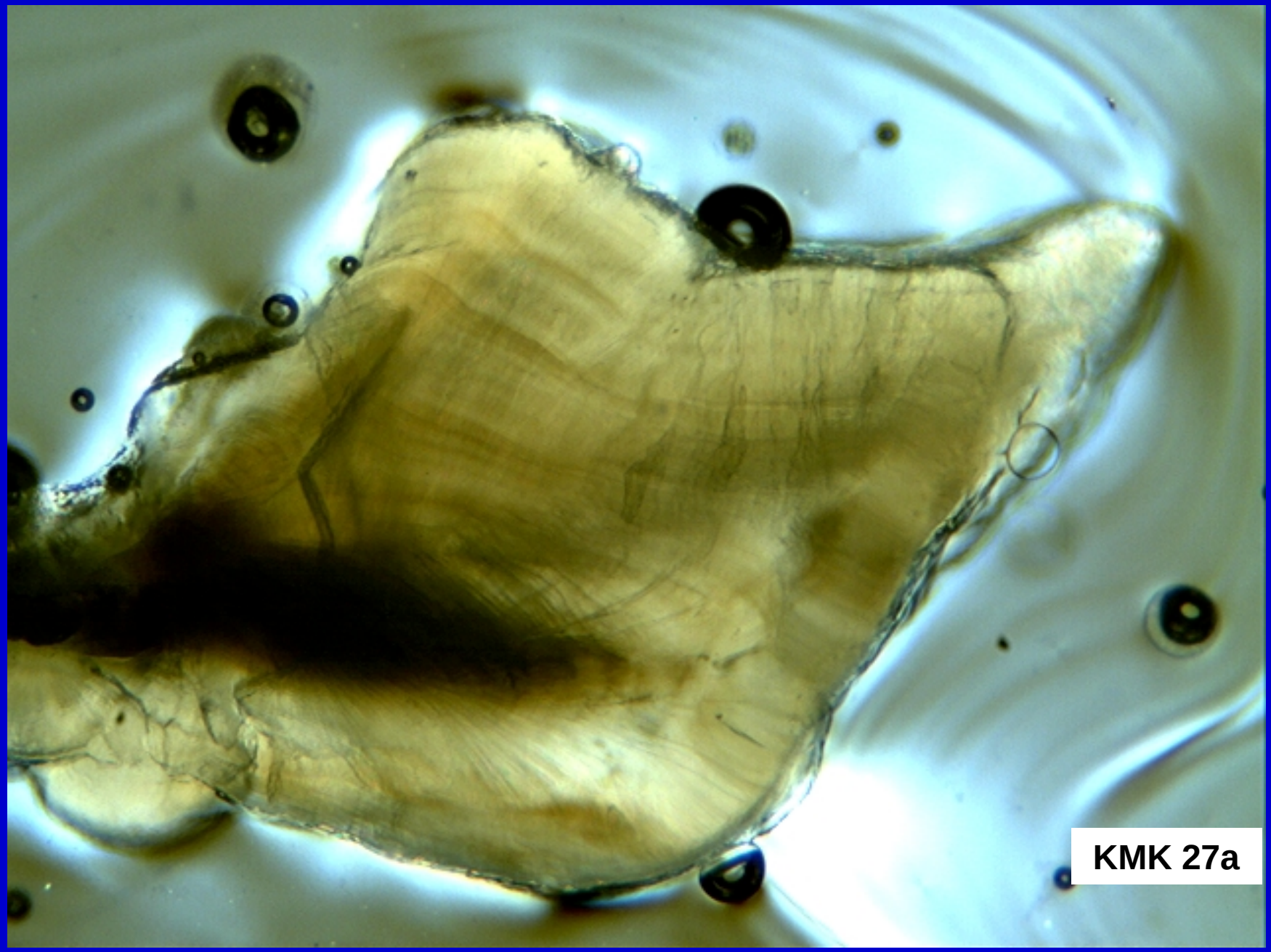
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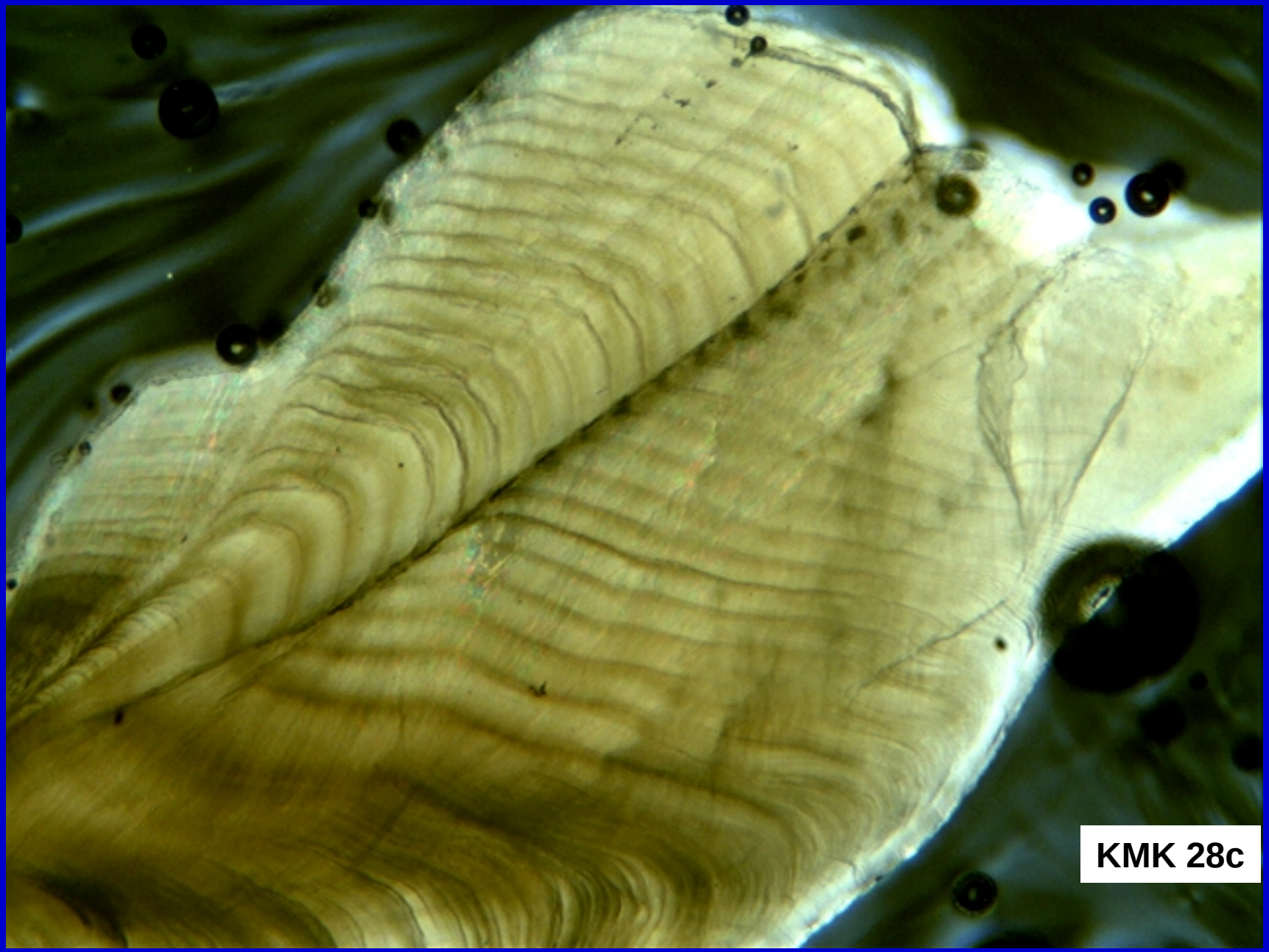
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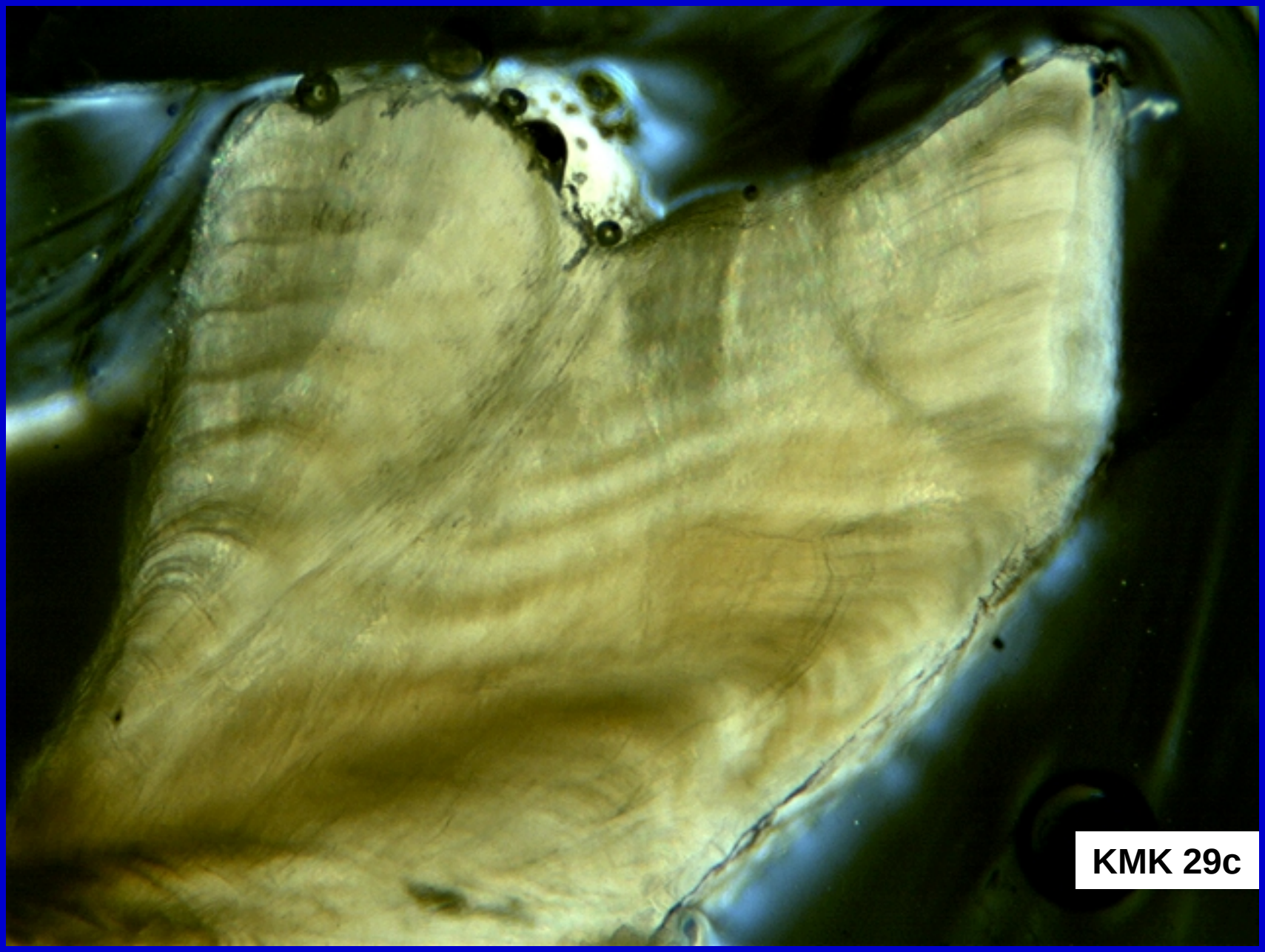
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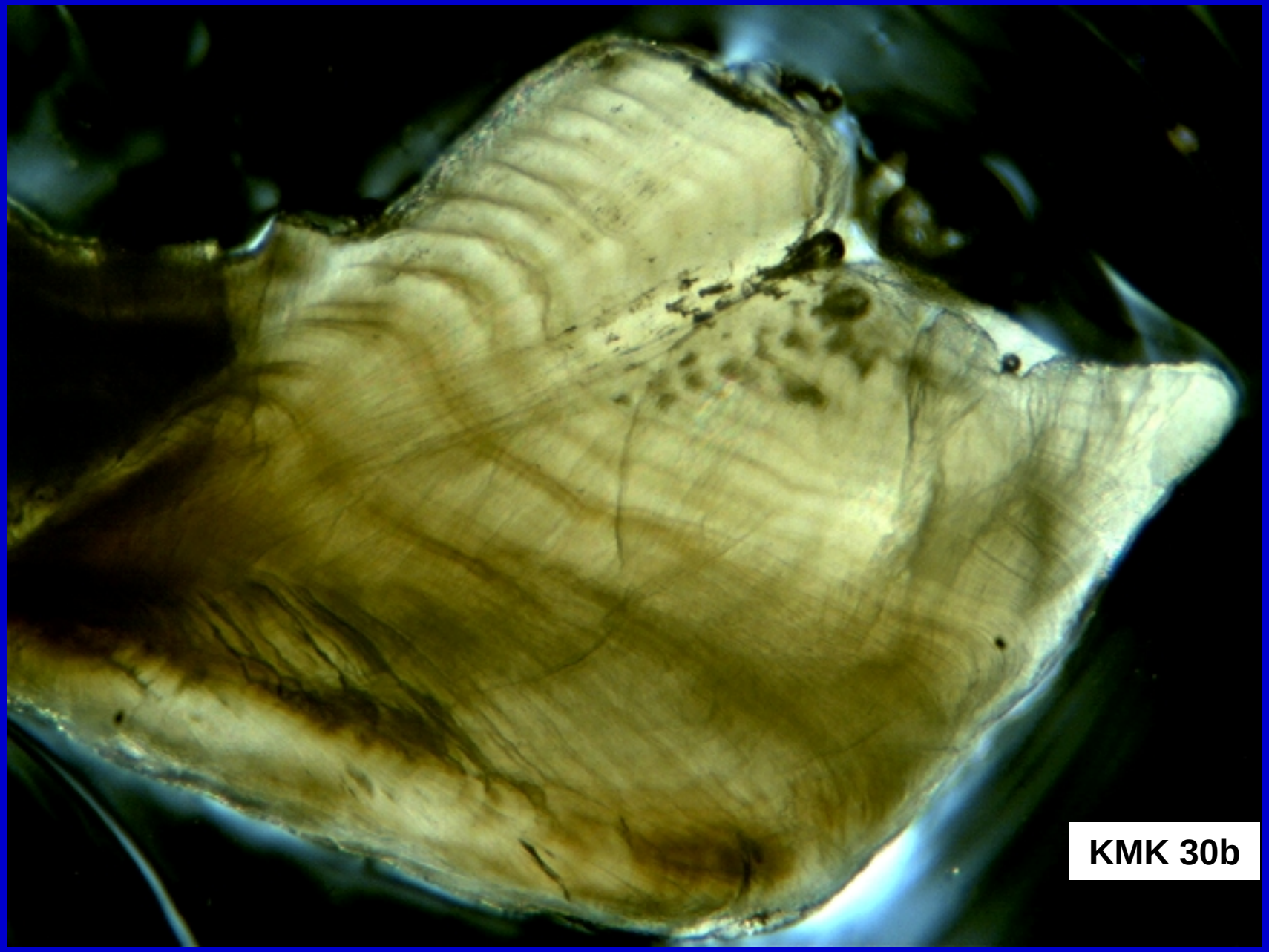
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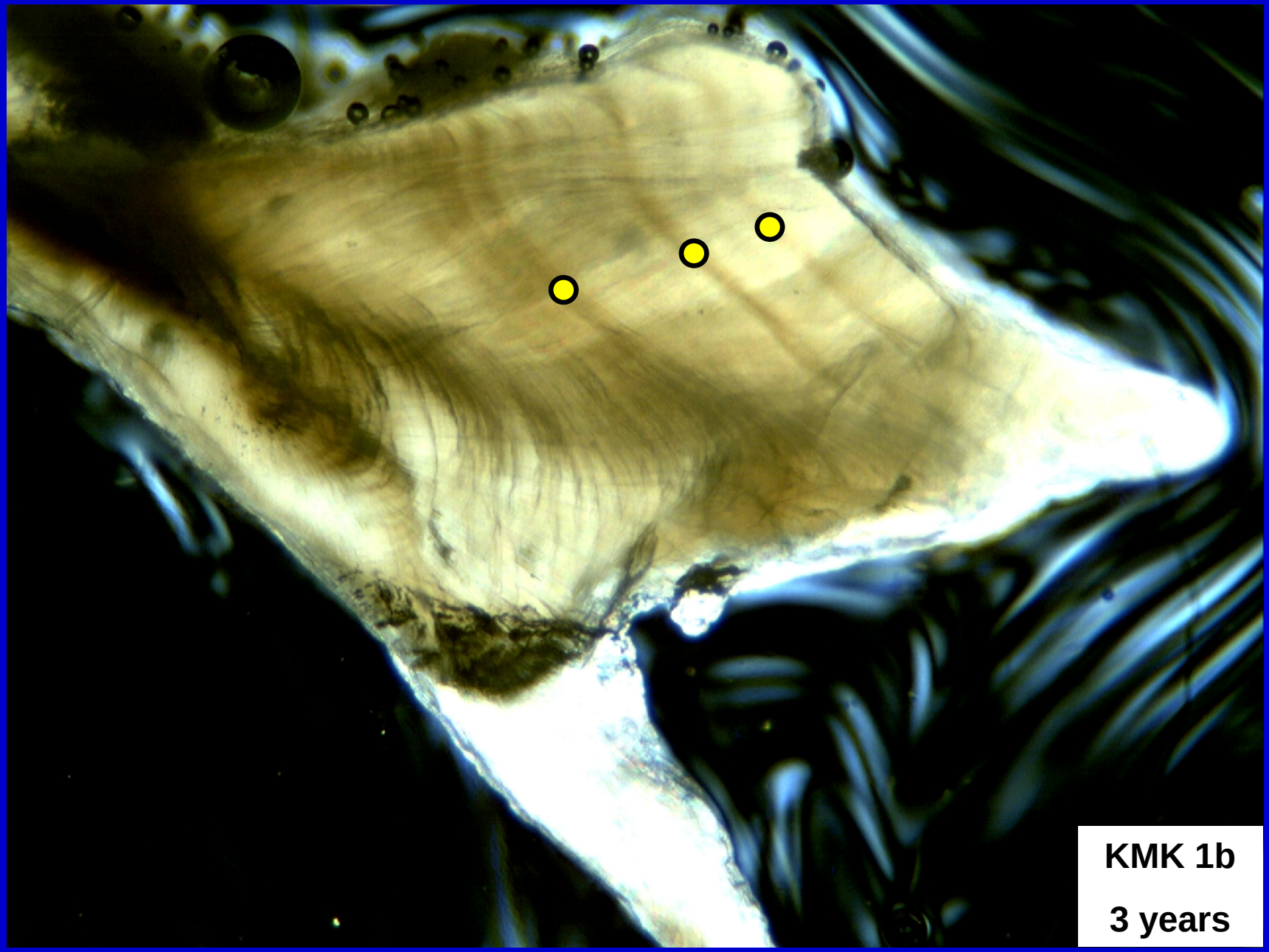
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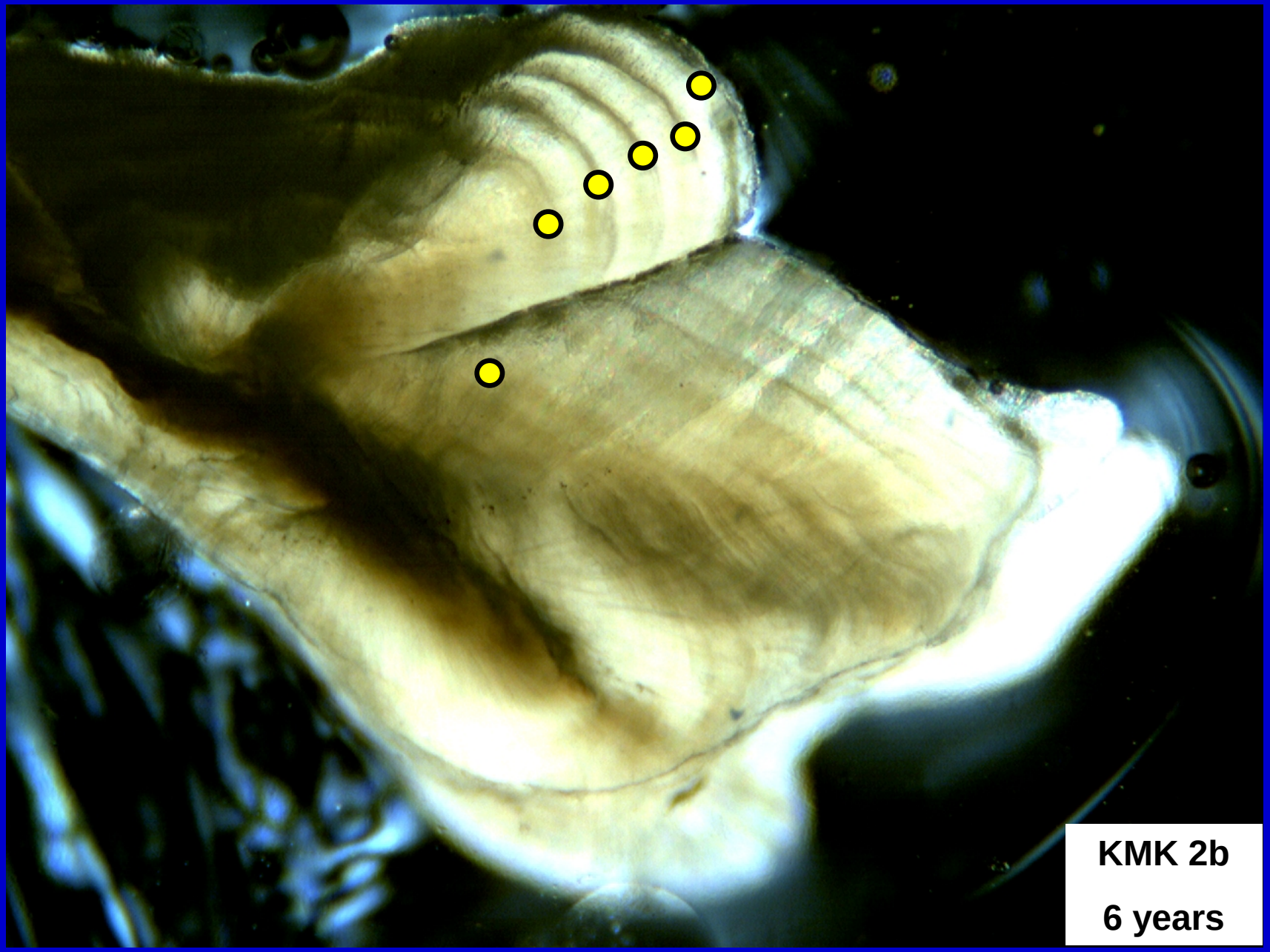
3 years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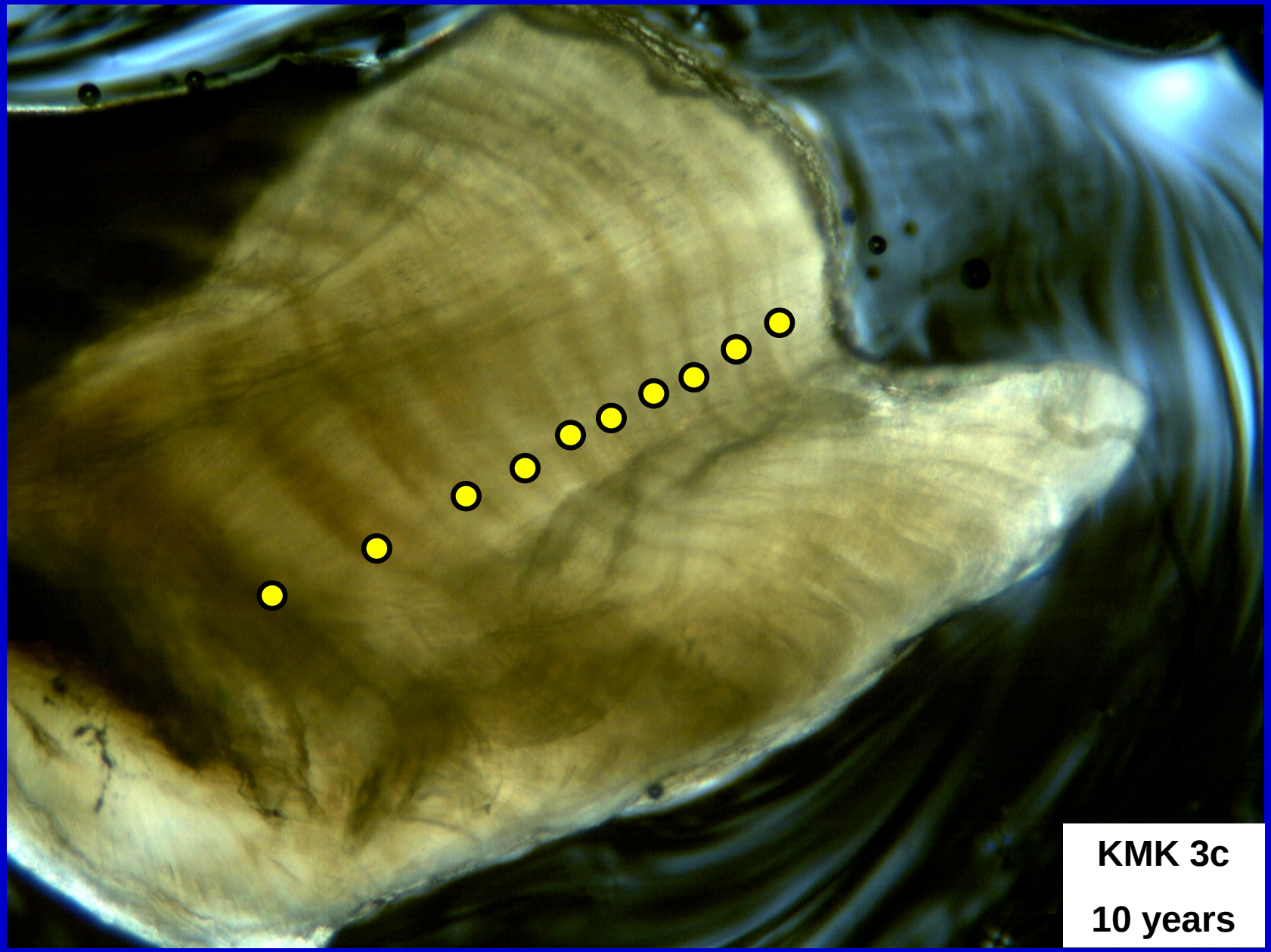
6 years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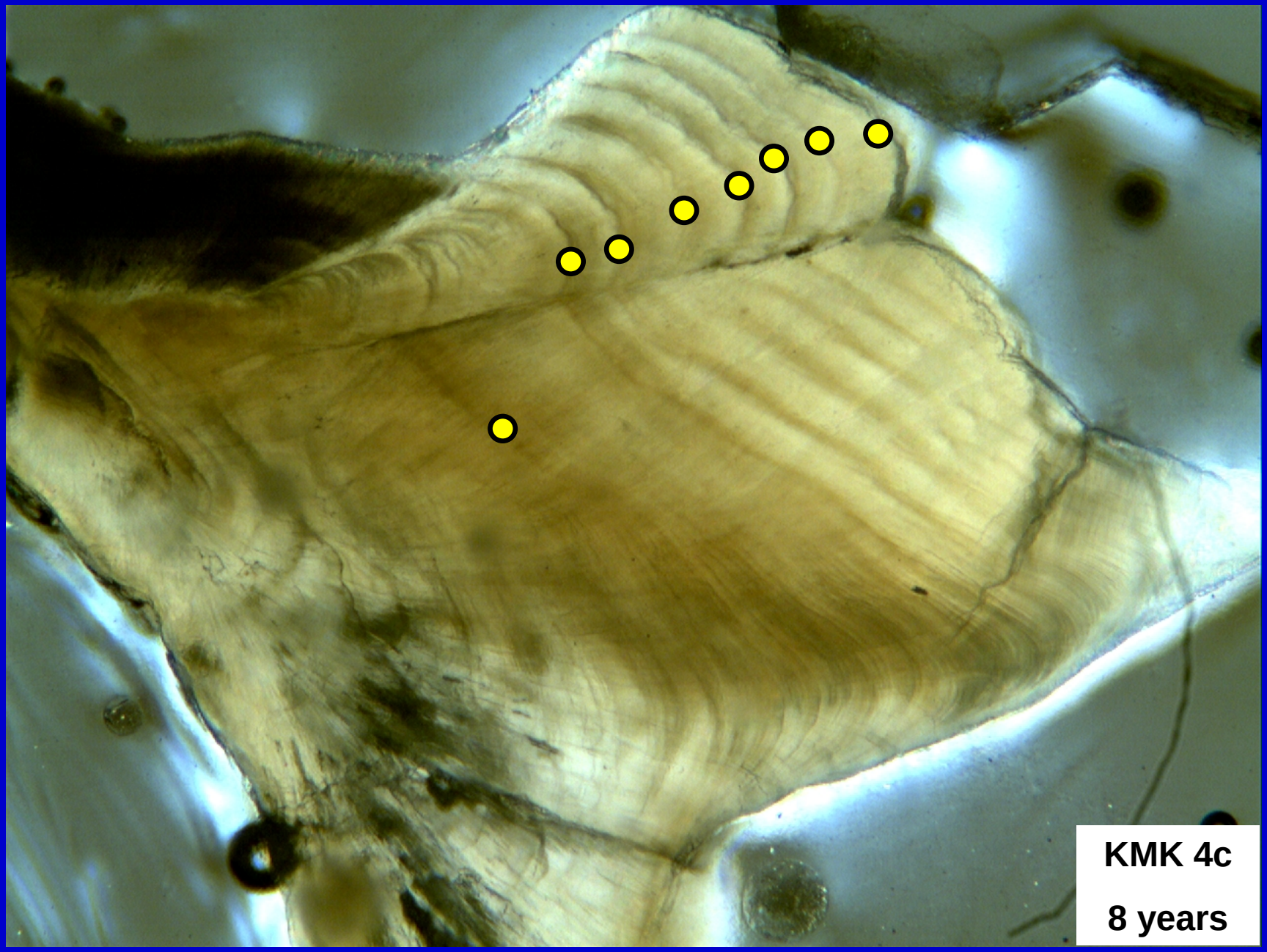
10 years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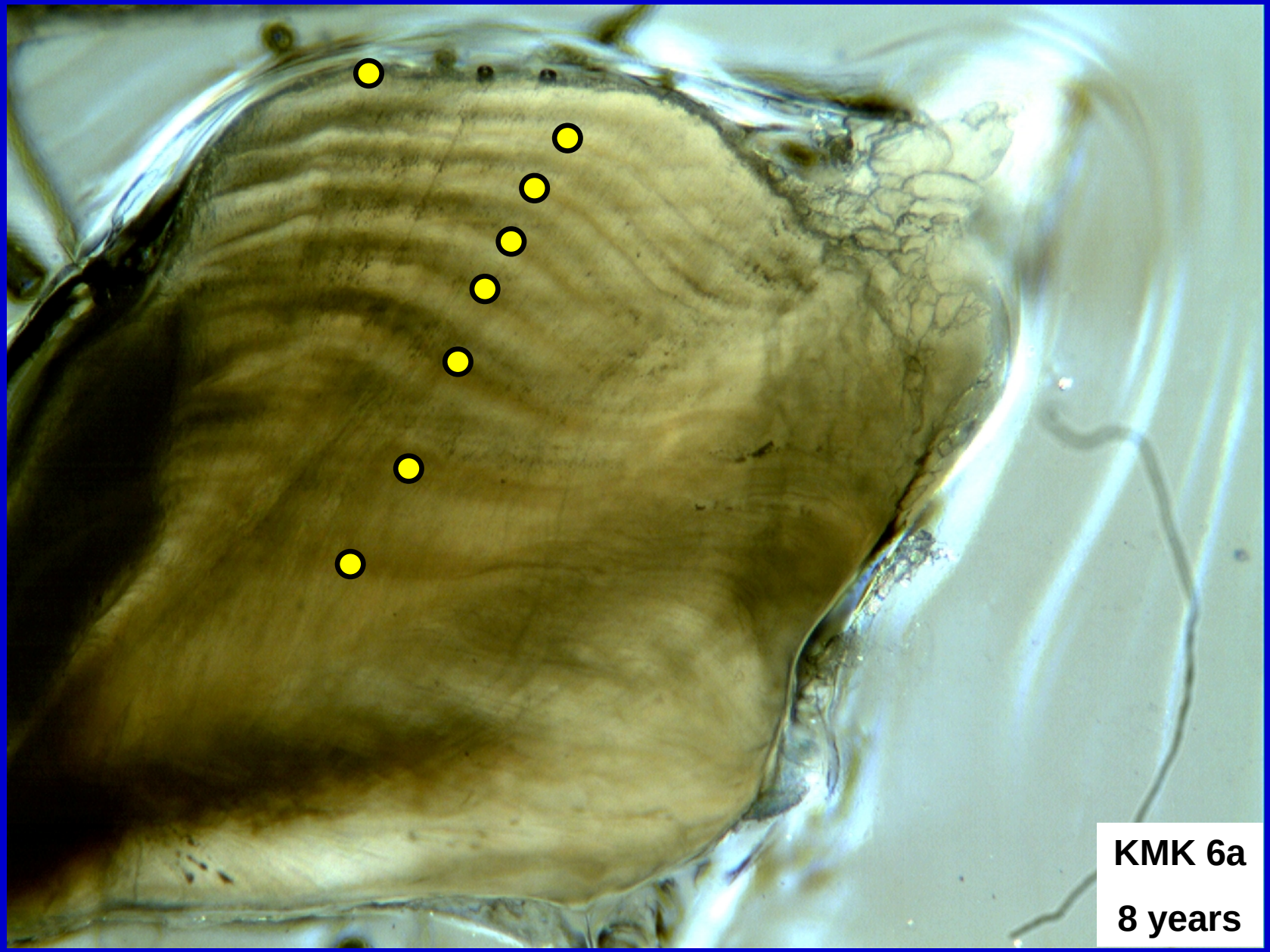
8 years

KMK 5a
7 years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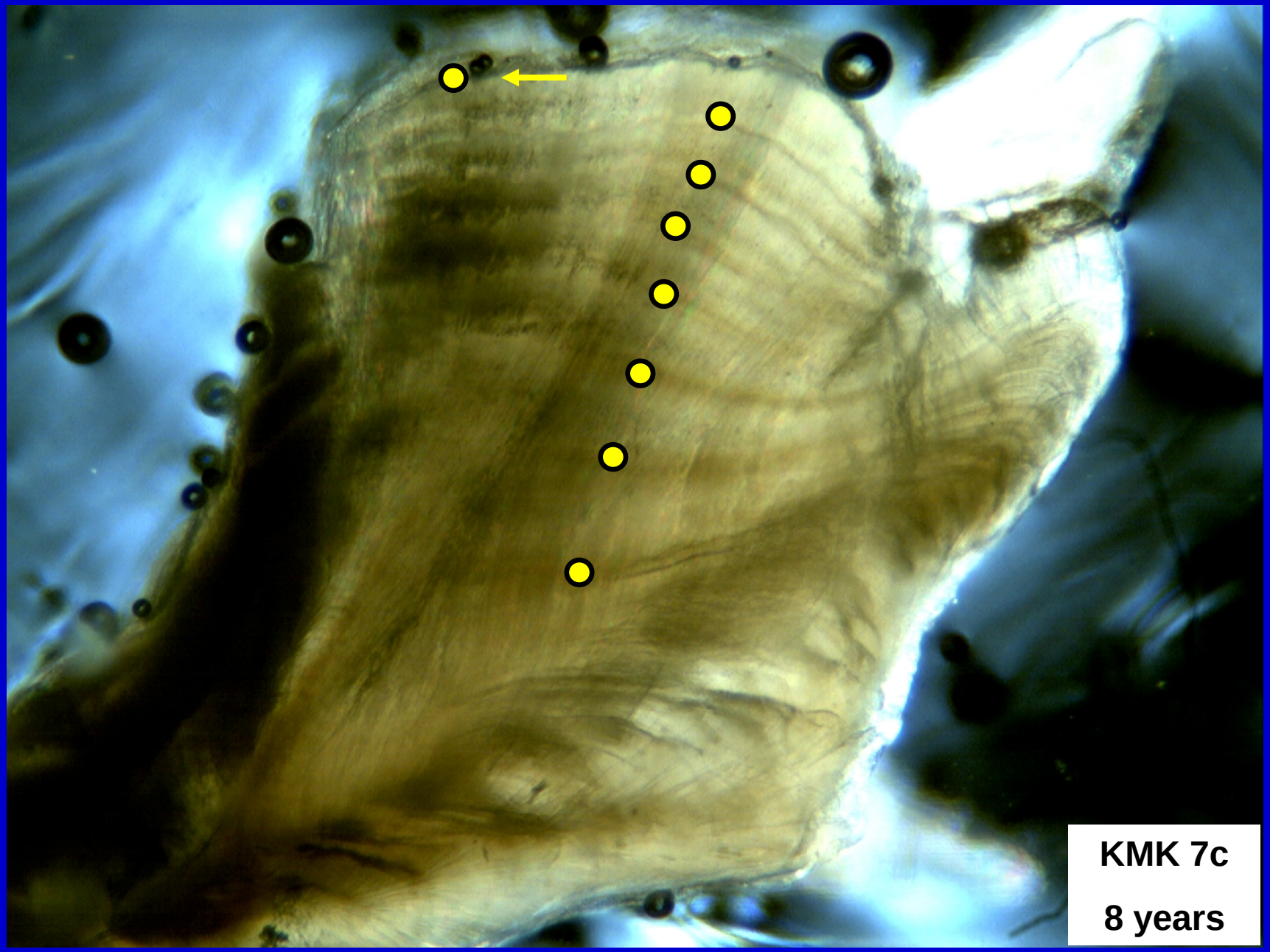
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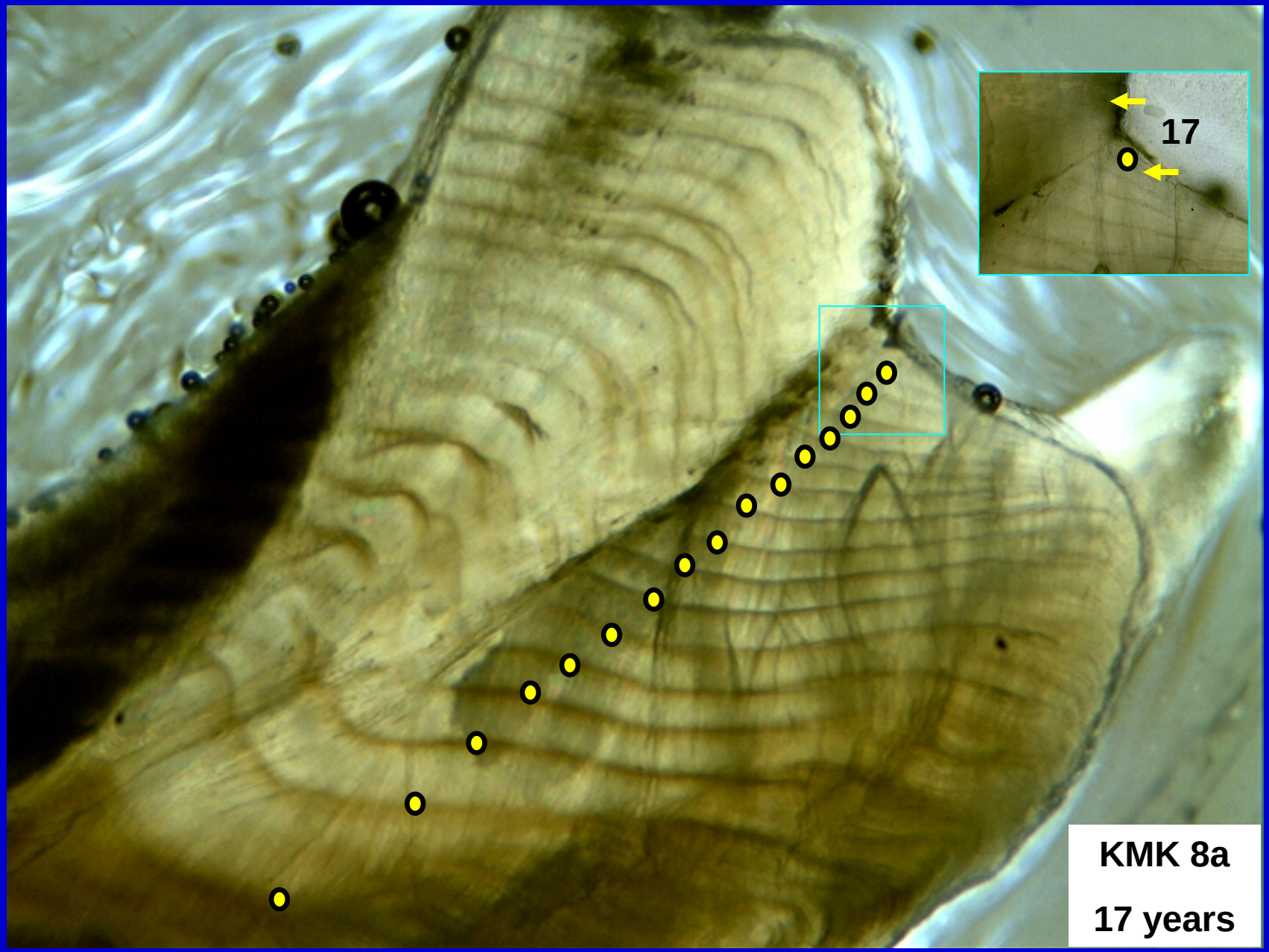
8 years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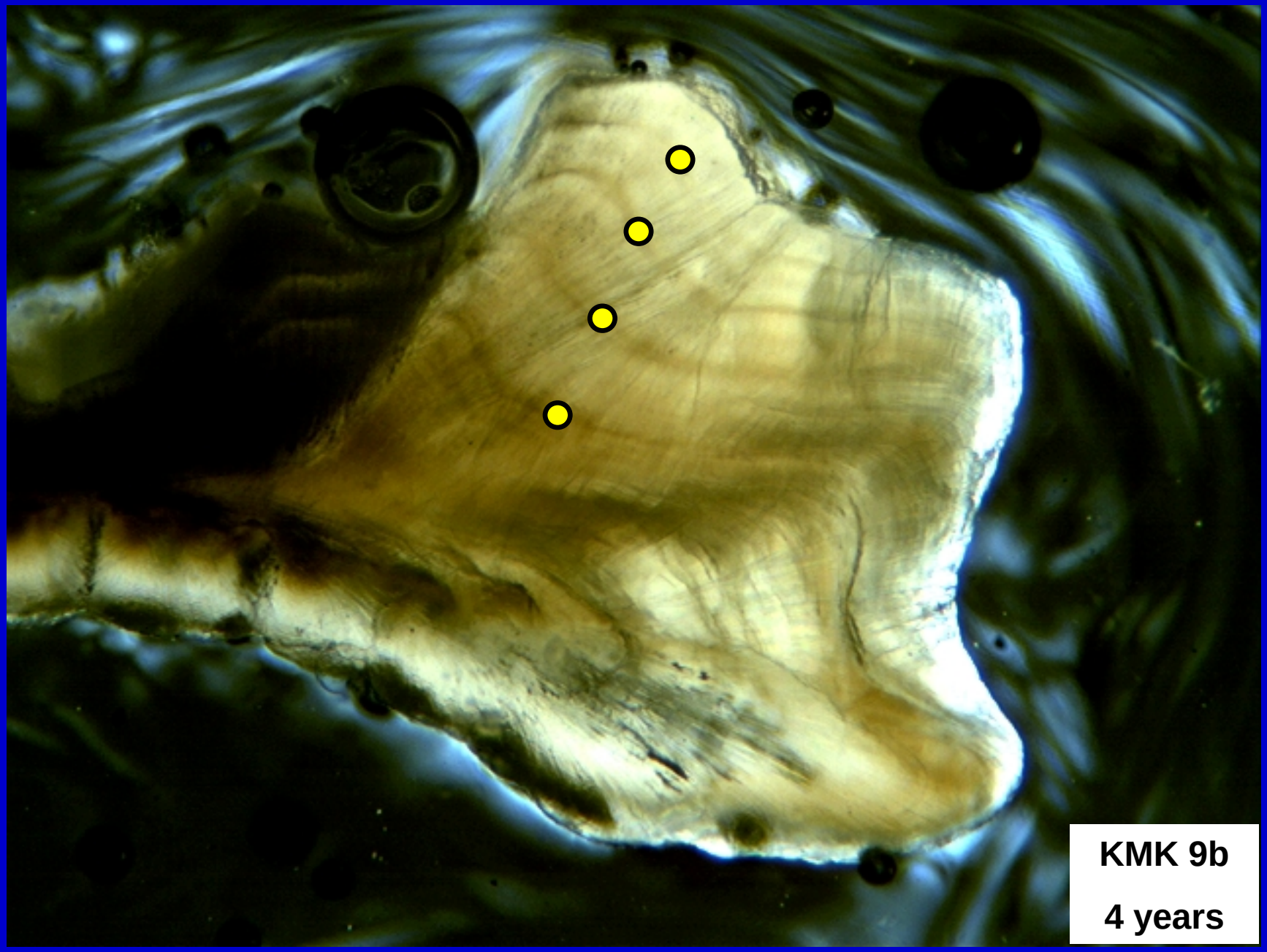
17 years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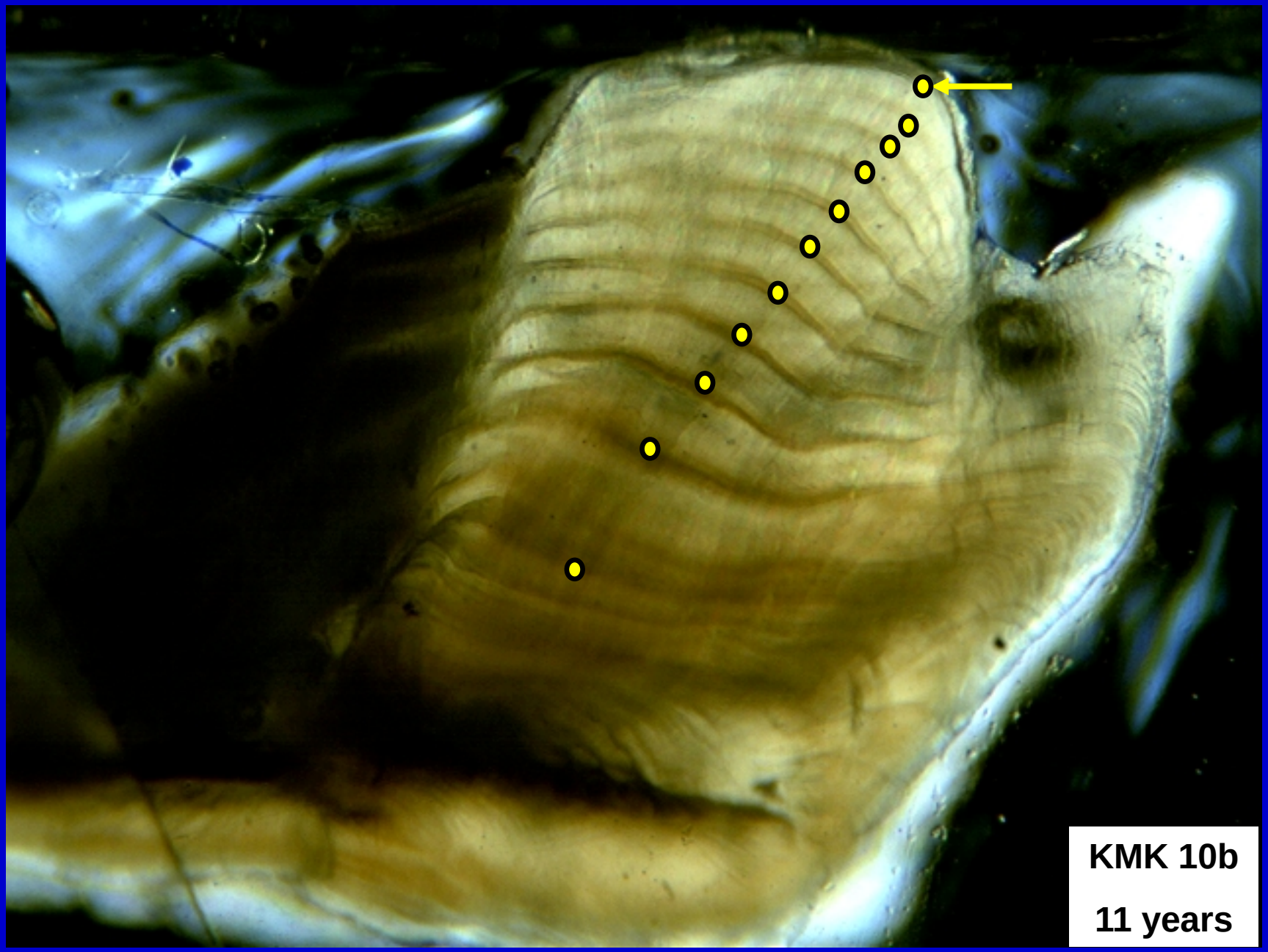
4 years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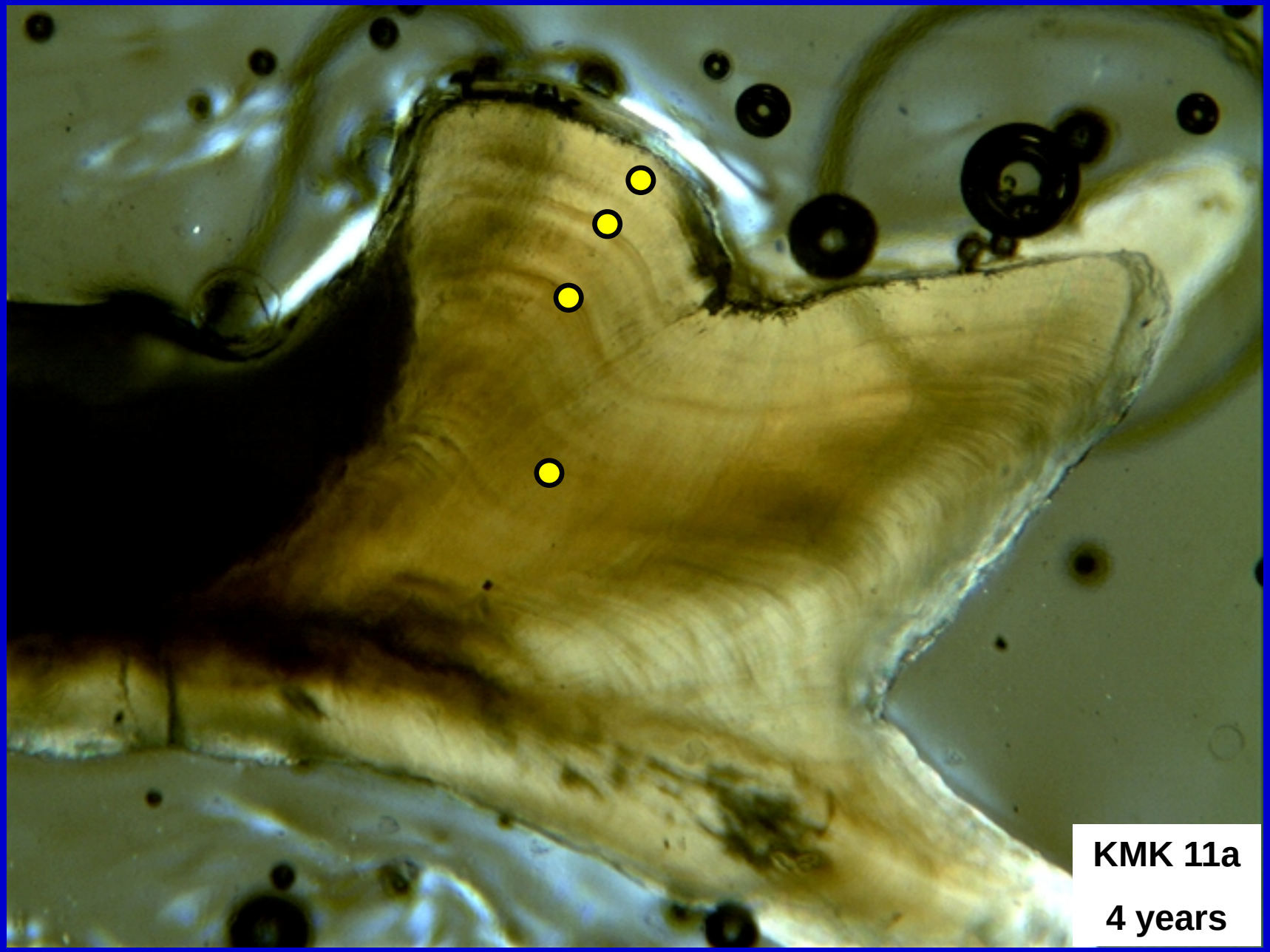
11 years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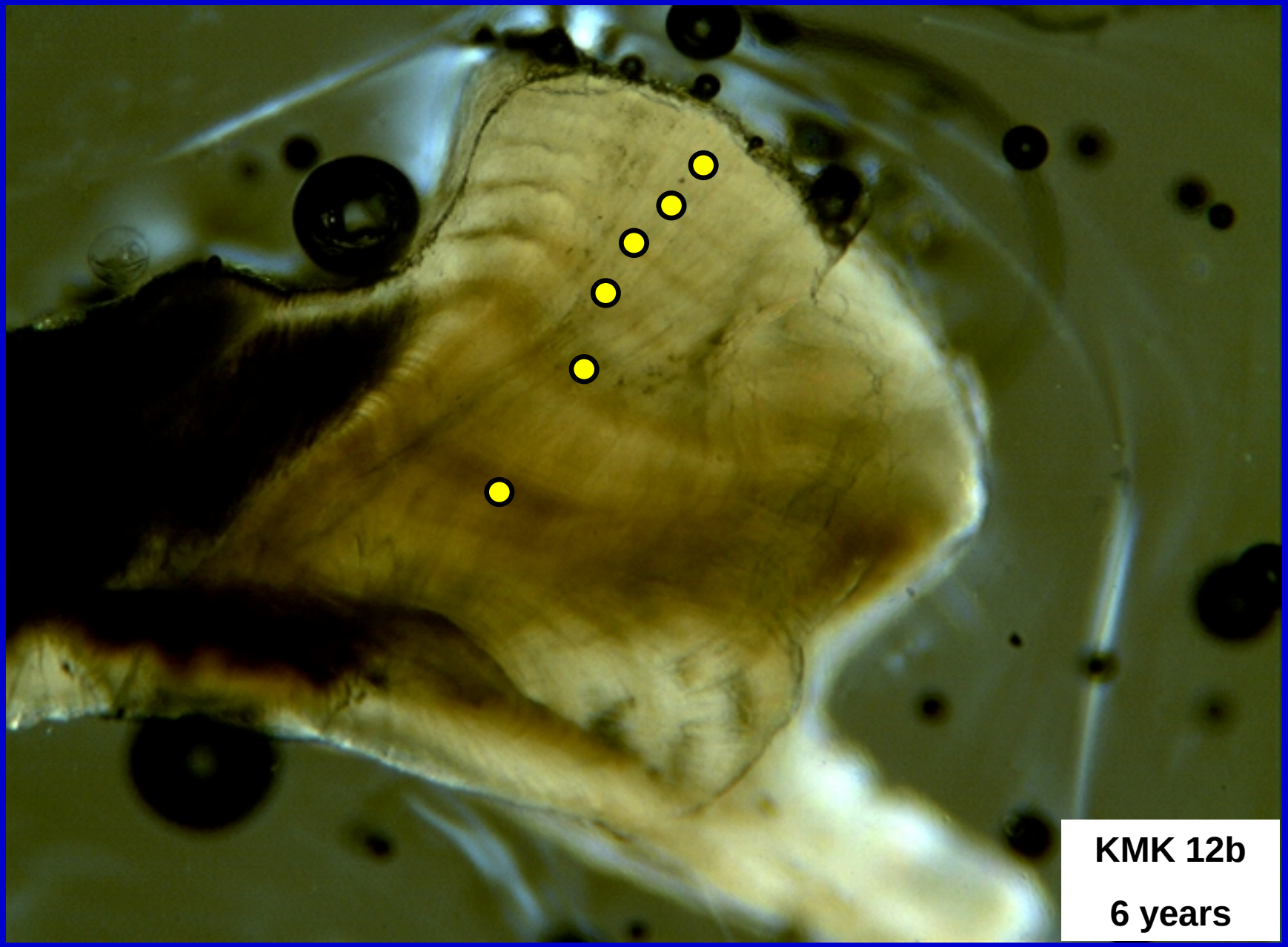
4 years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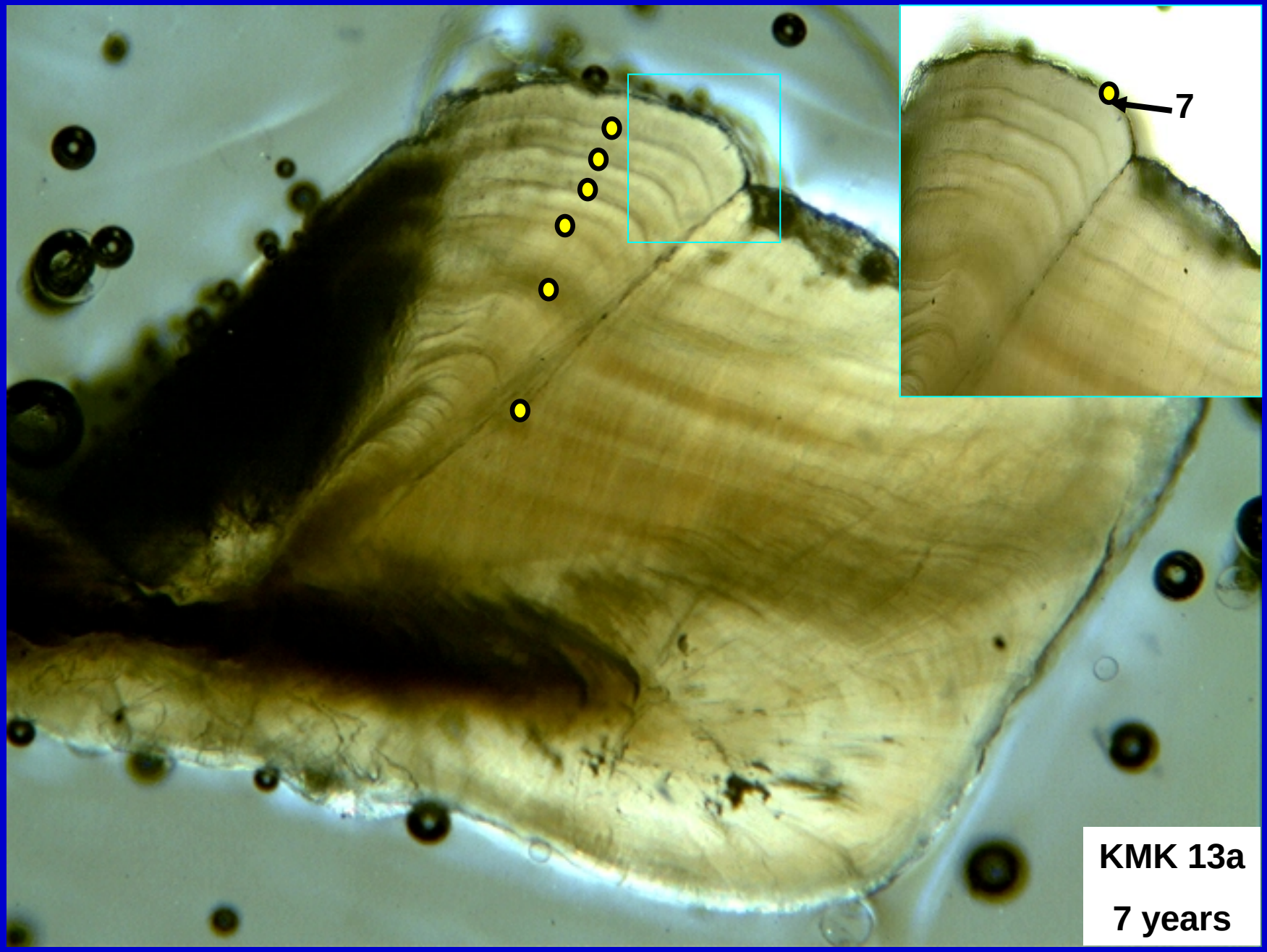
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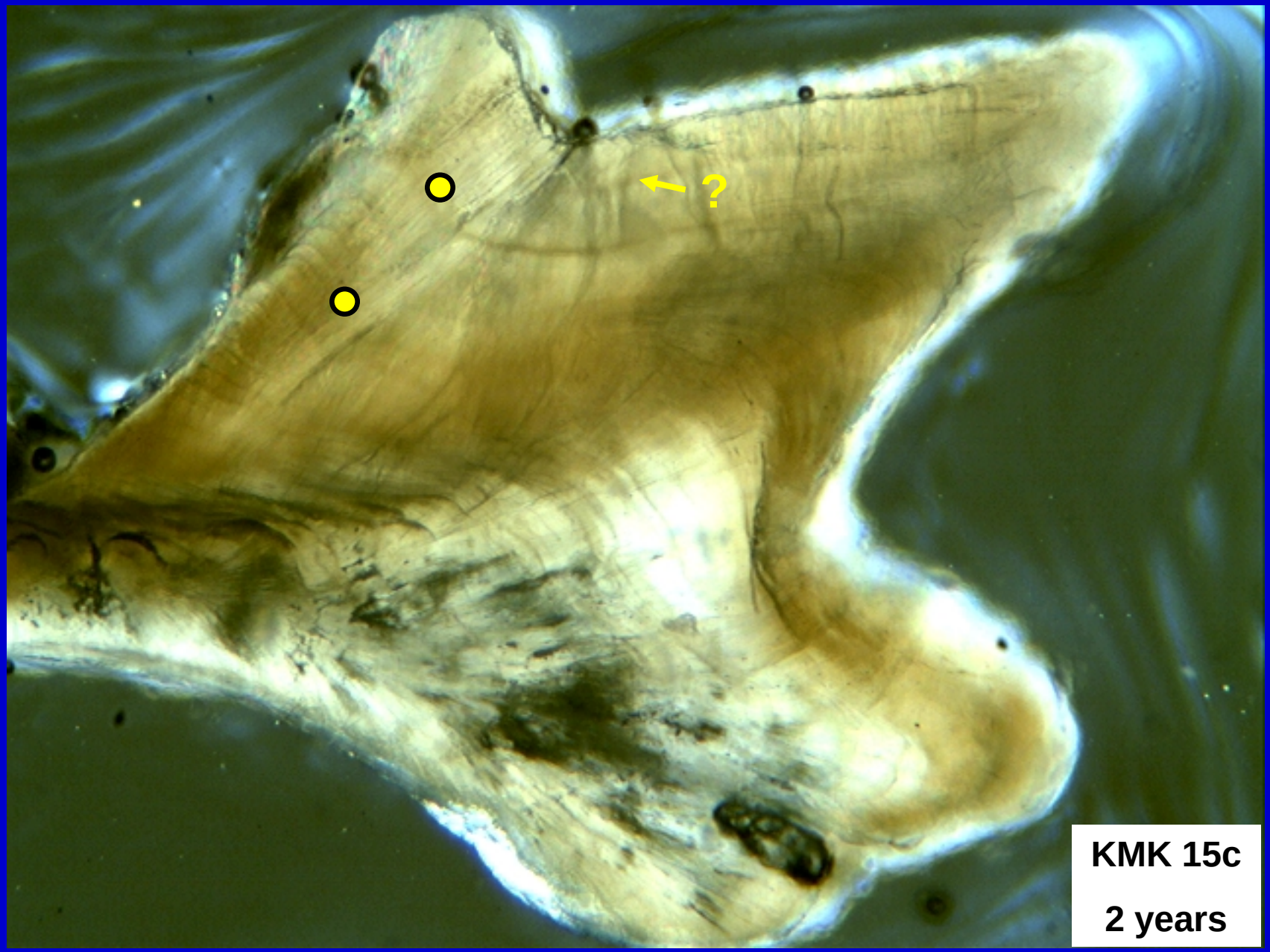
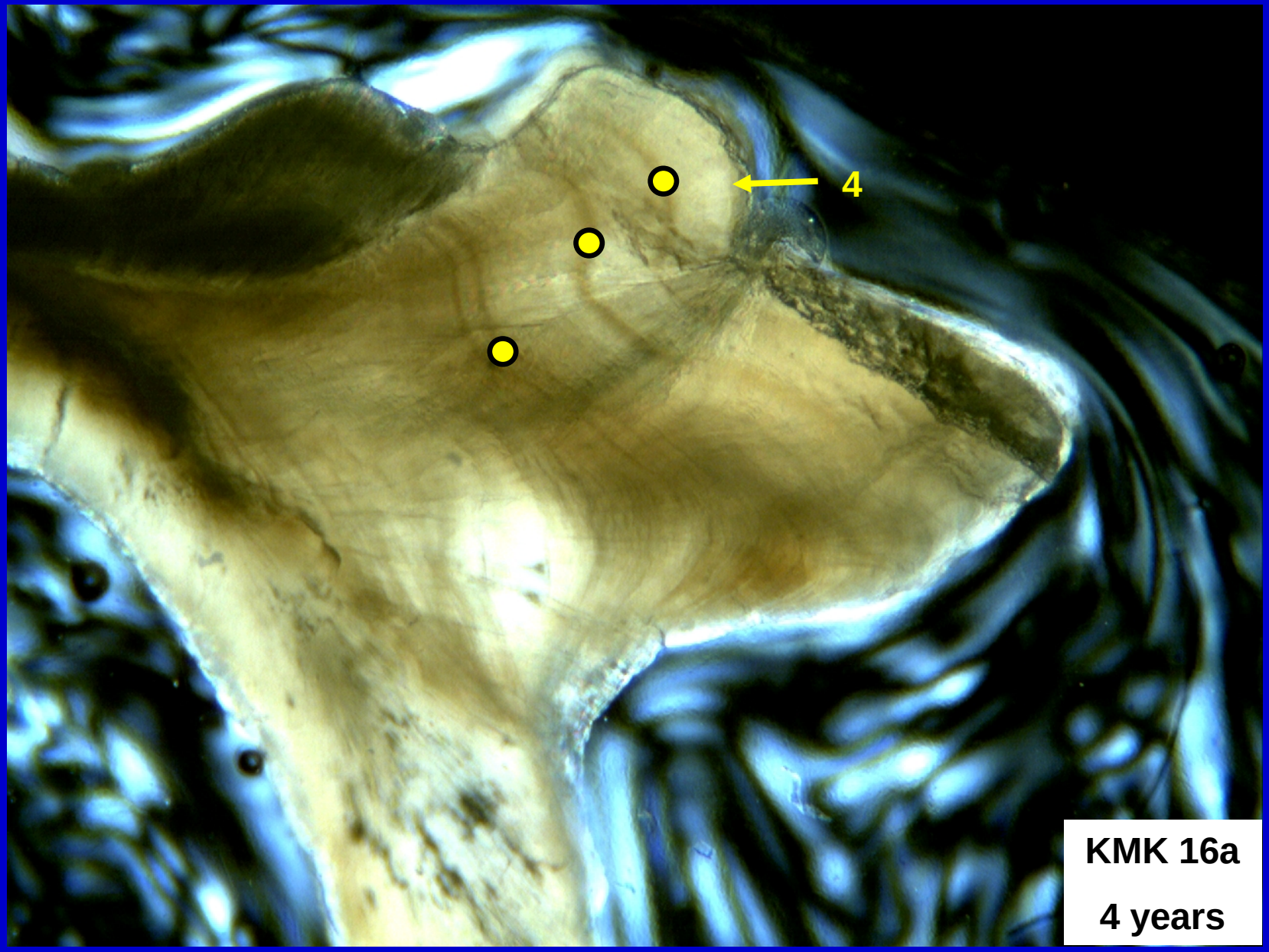
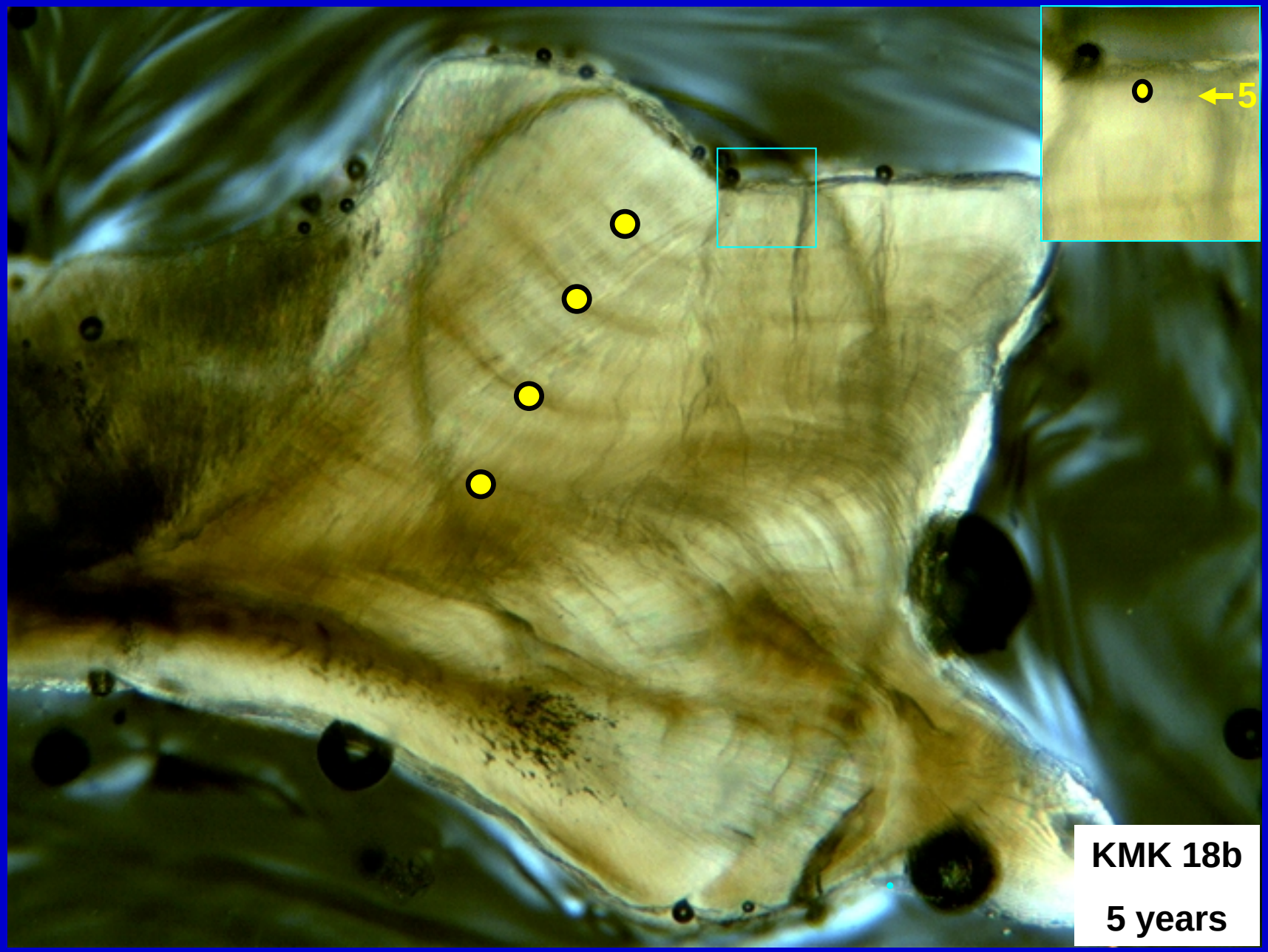
7 years

KMK 14a
15 years

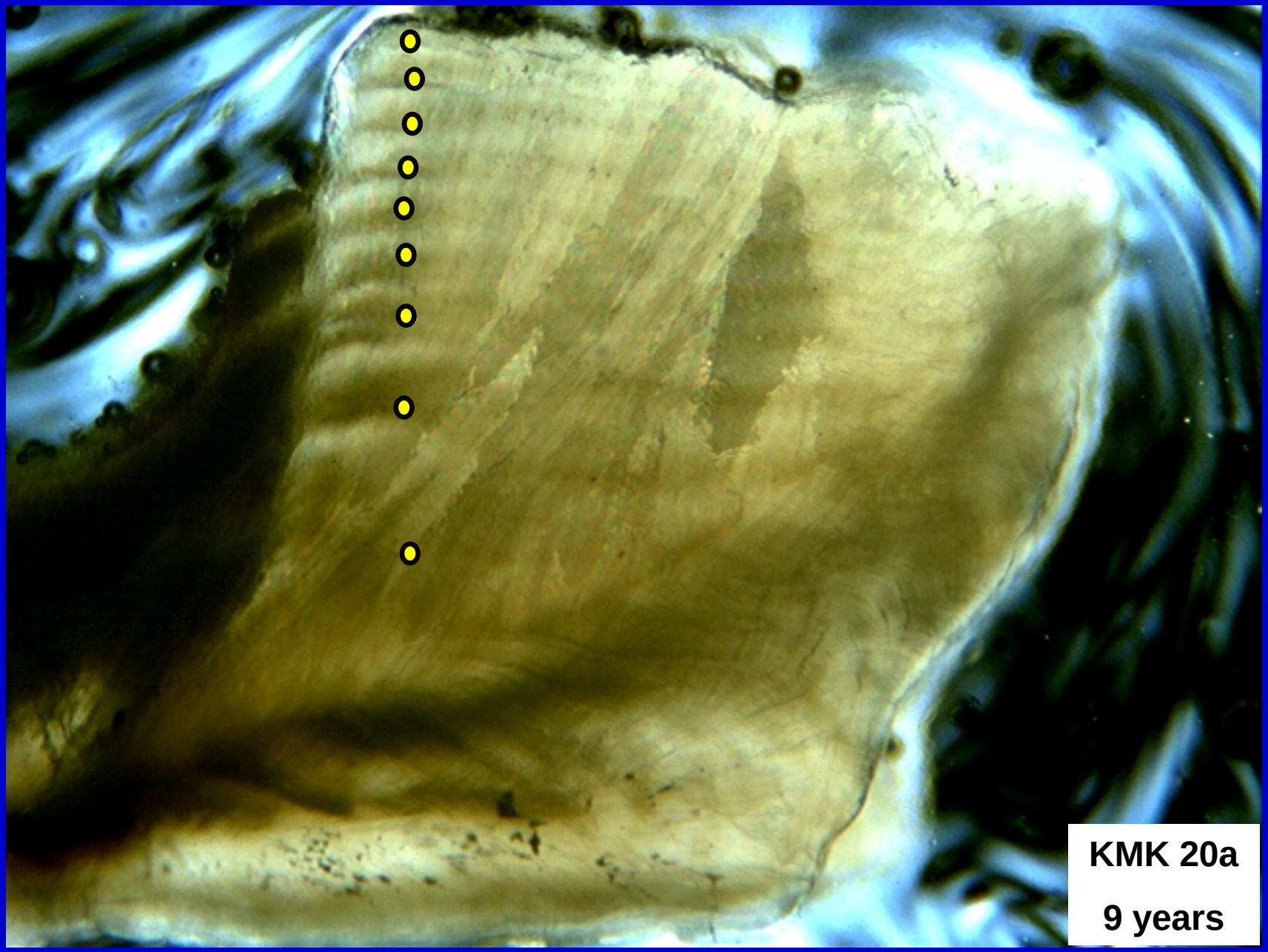

?
KMK 15c
2 years

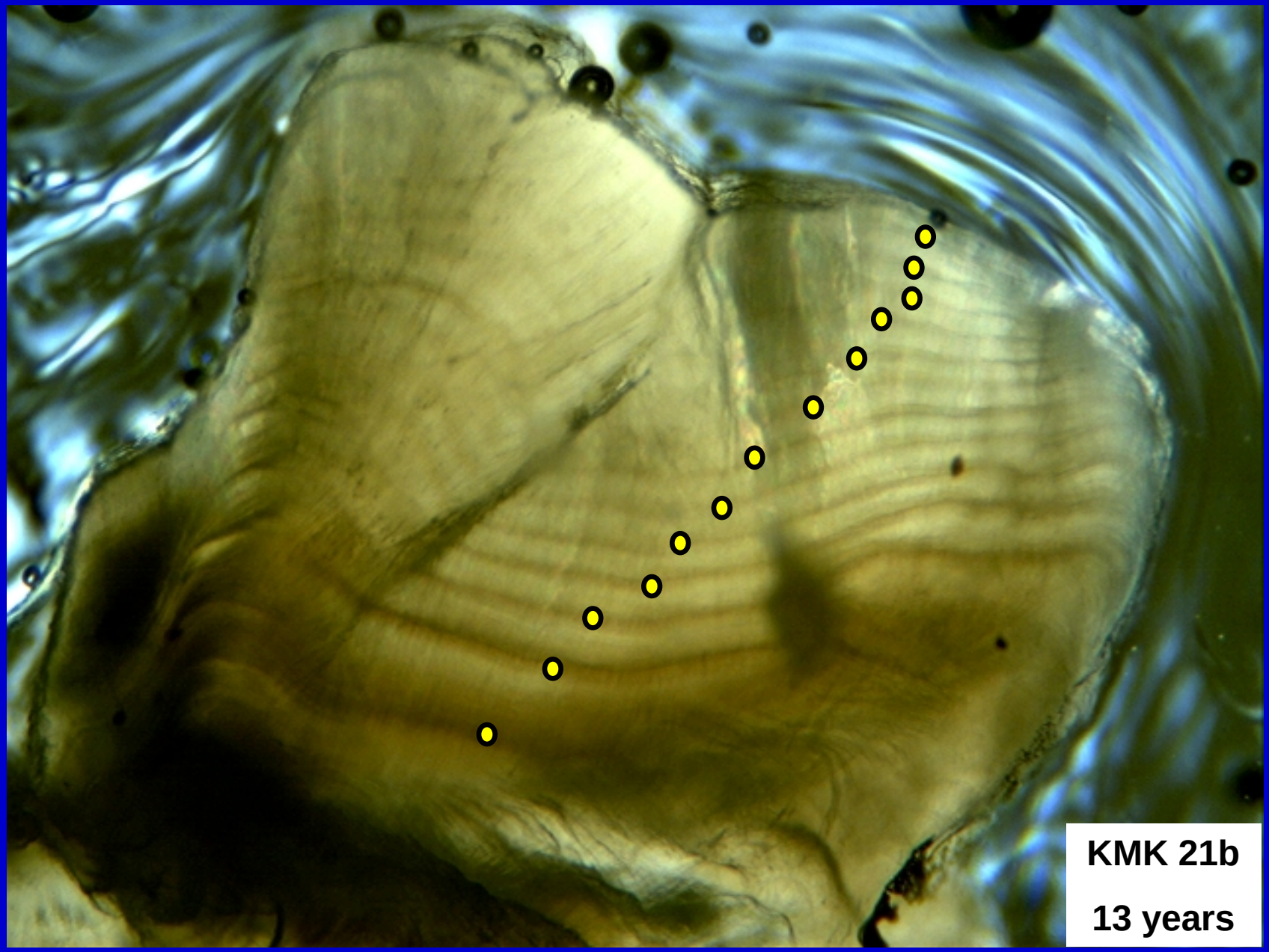

4
KMK 16a
4 years

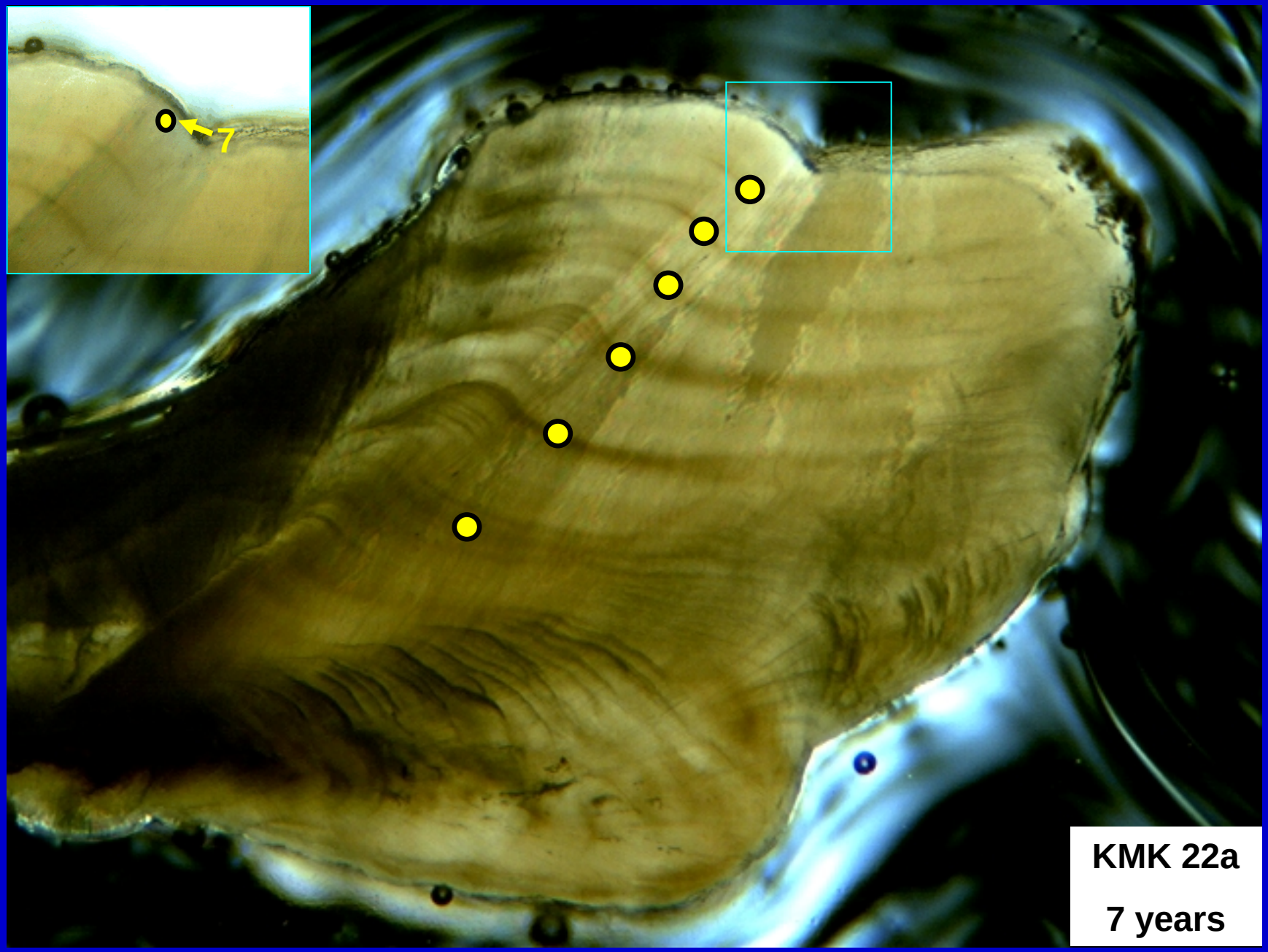
10
KMK 17b
10 years

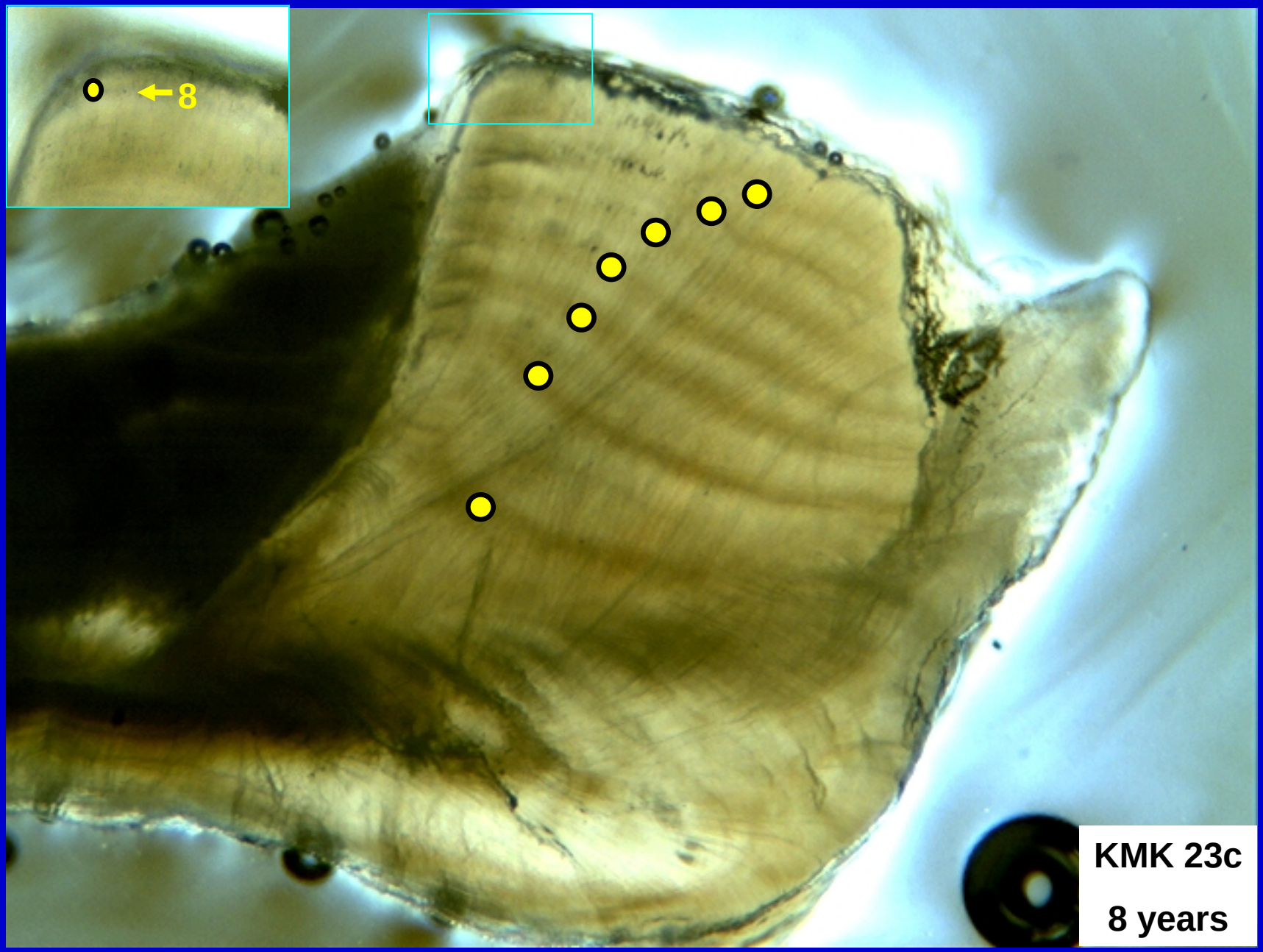

5
KMK 18b
5 years

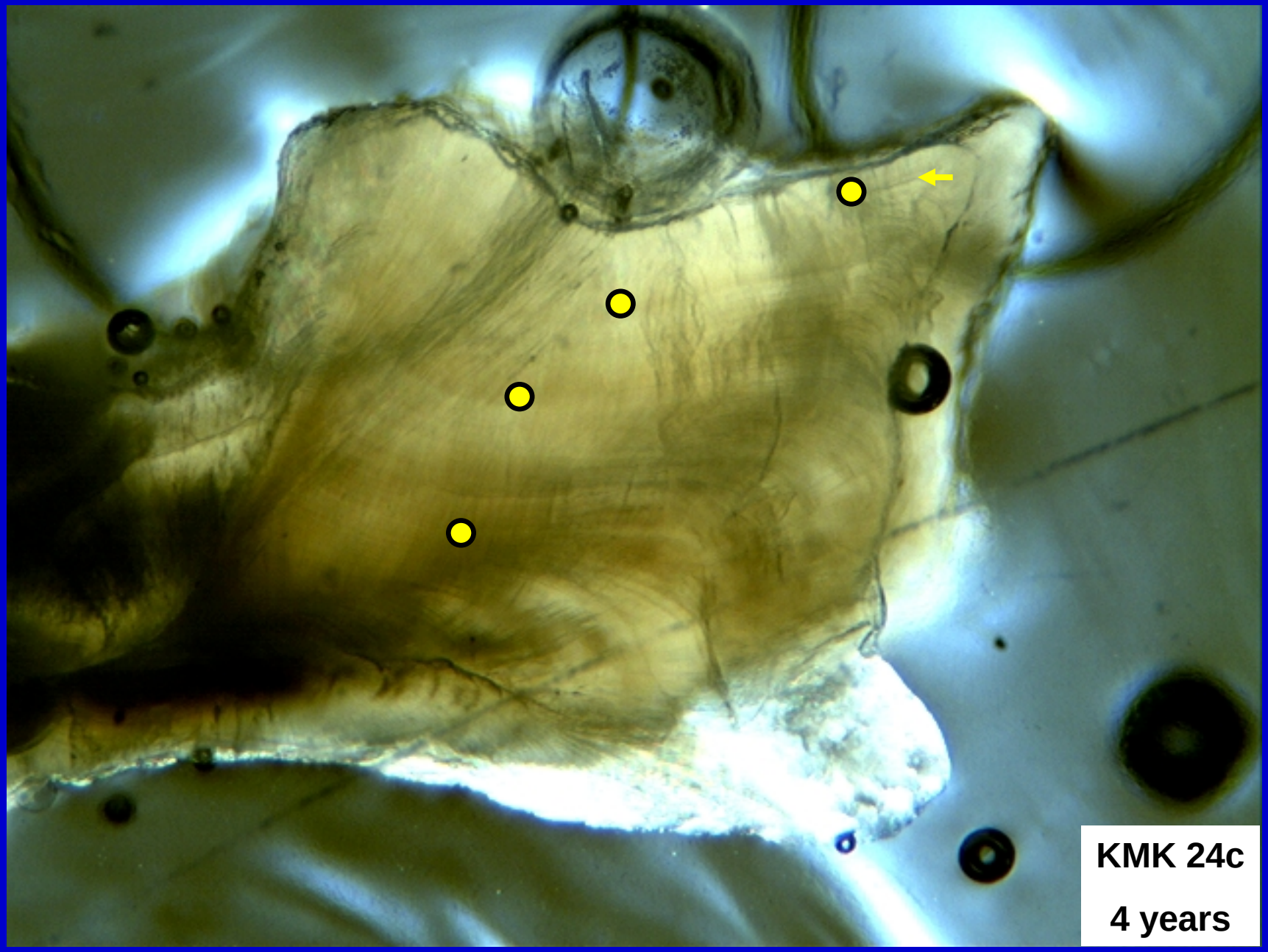
KMK 19b
7 years

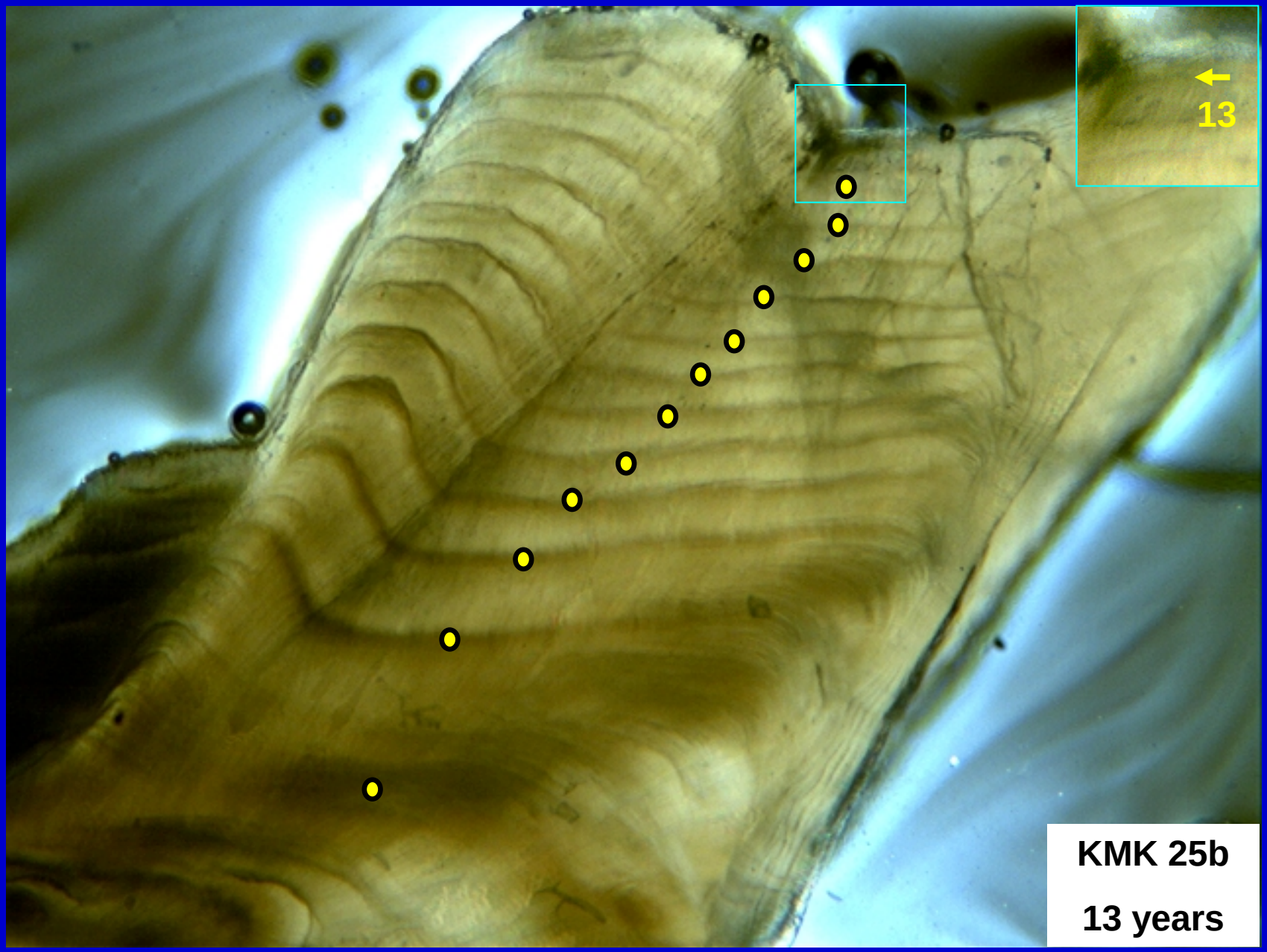

KMK 20a
9 years

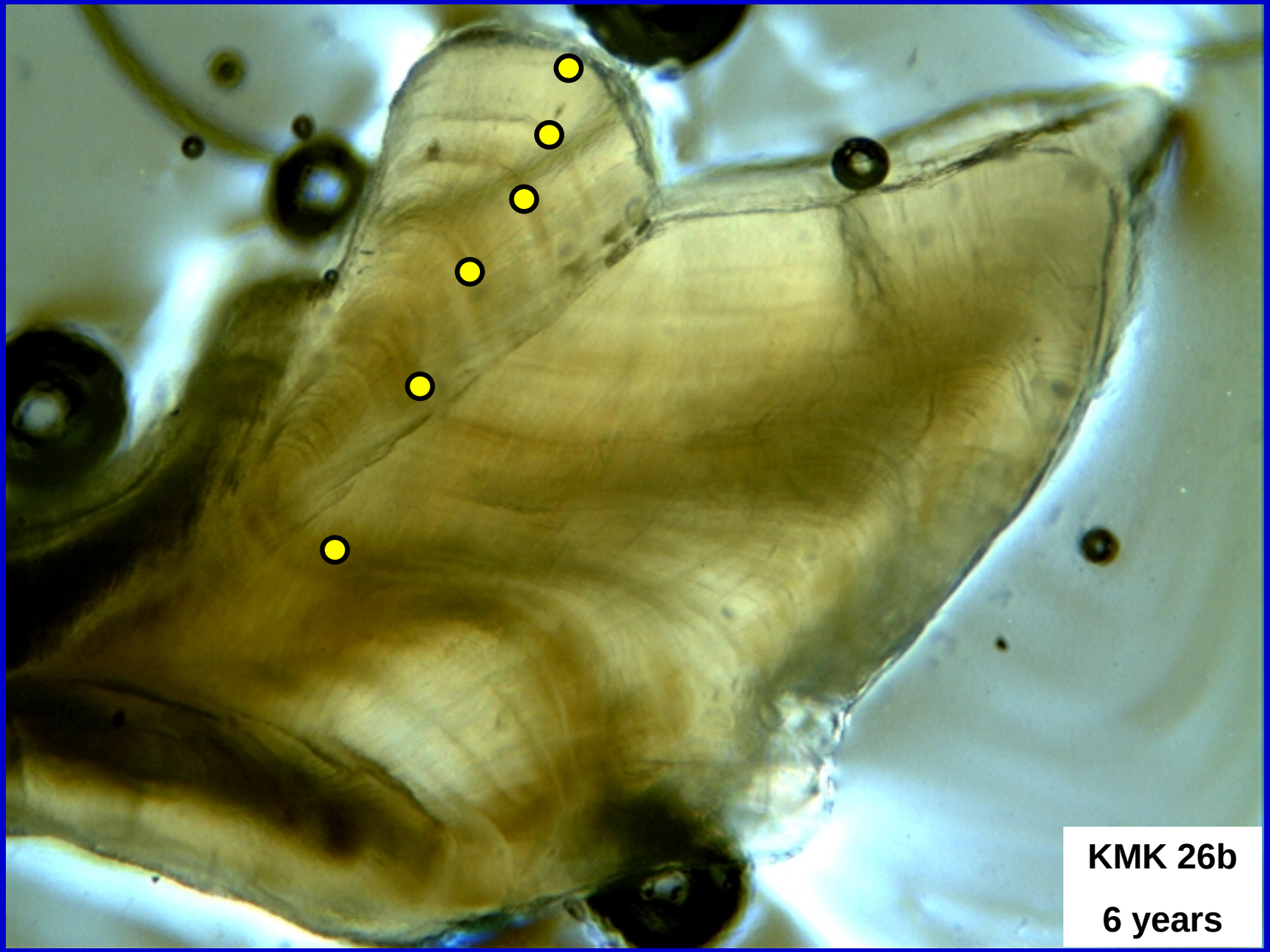

KMK 21b
13 years

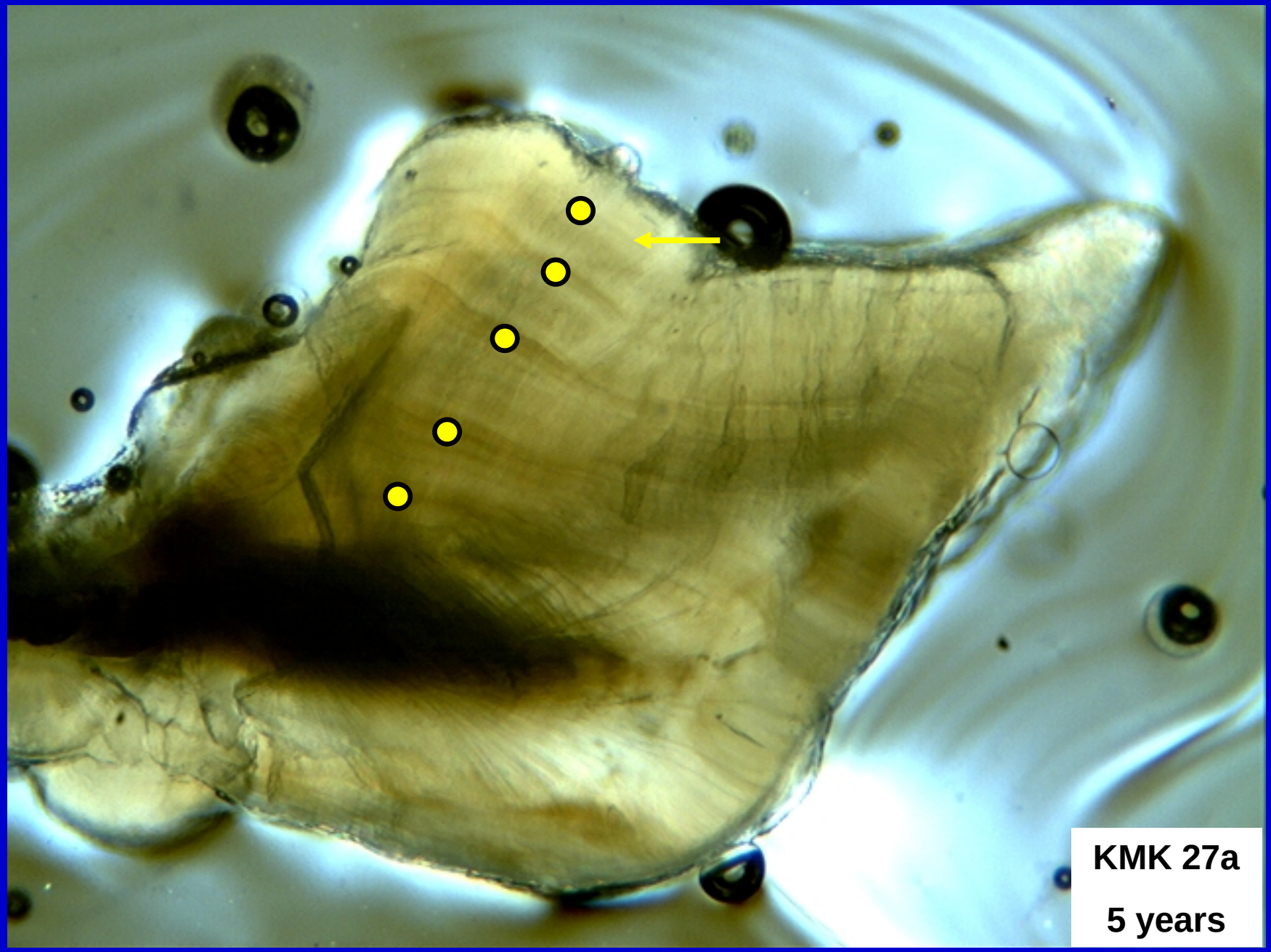

7
KMK 22a
7 years

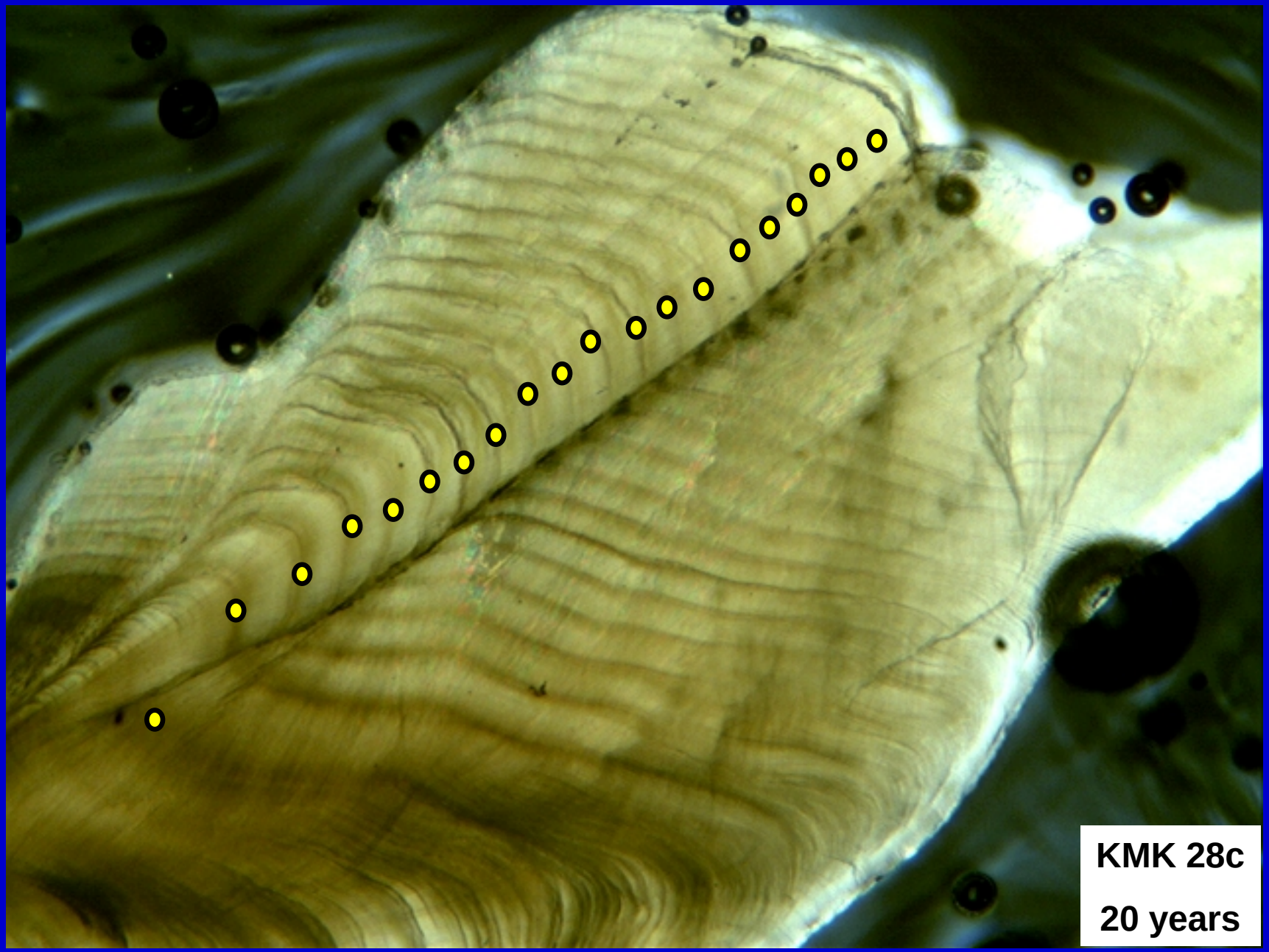

8
KMK 23c
8 years

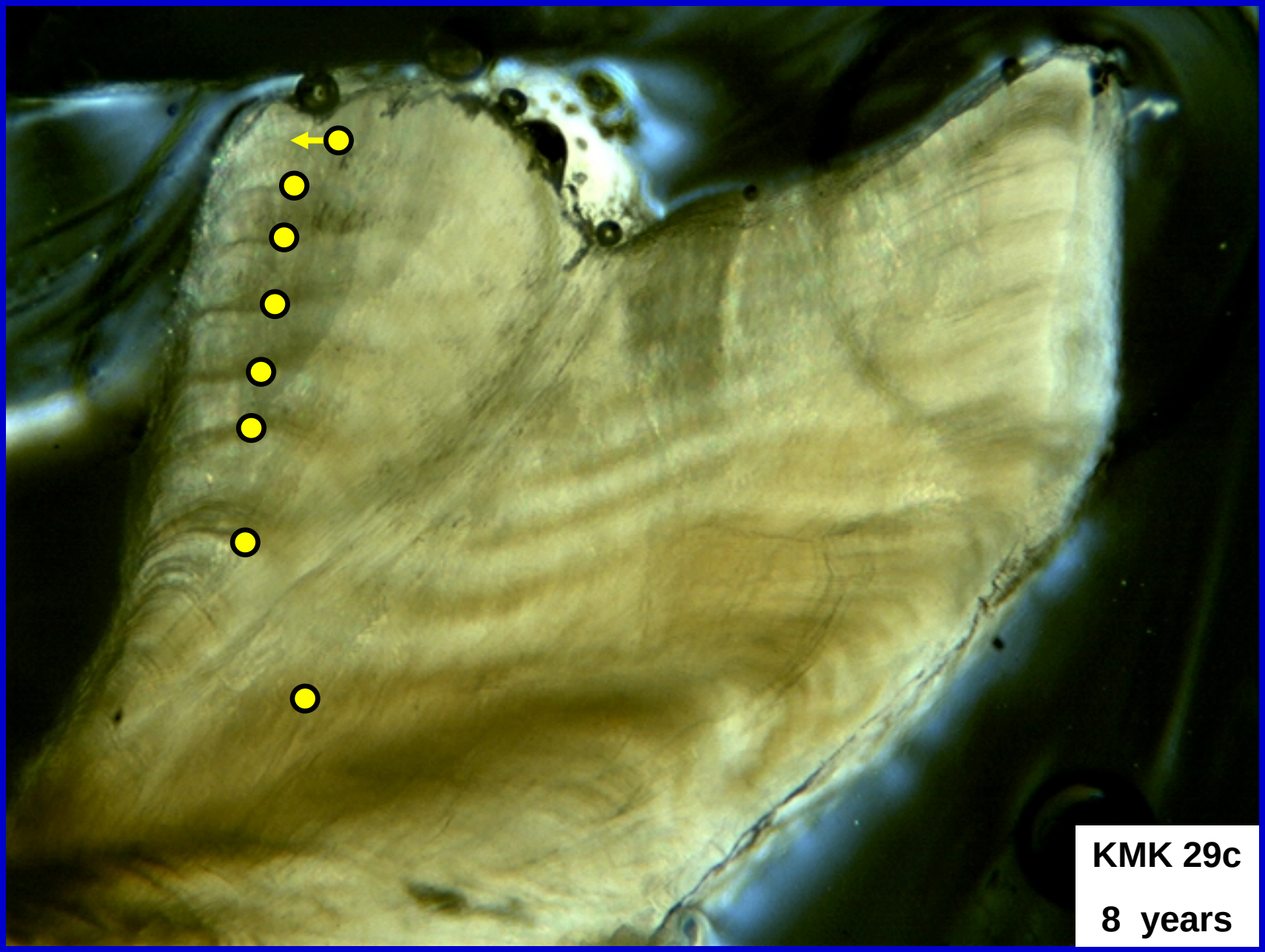

KMK 24c
4 years

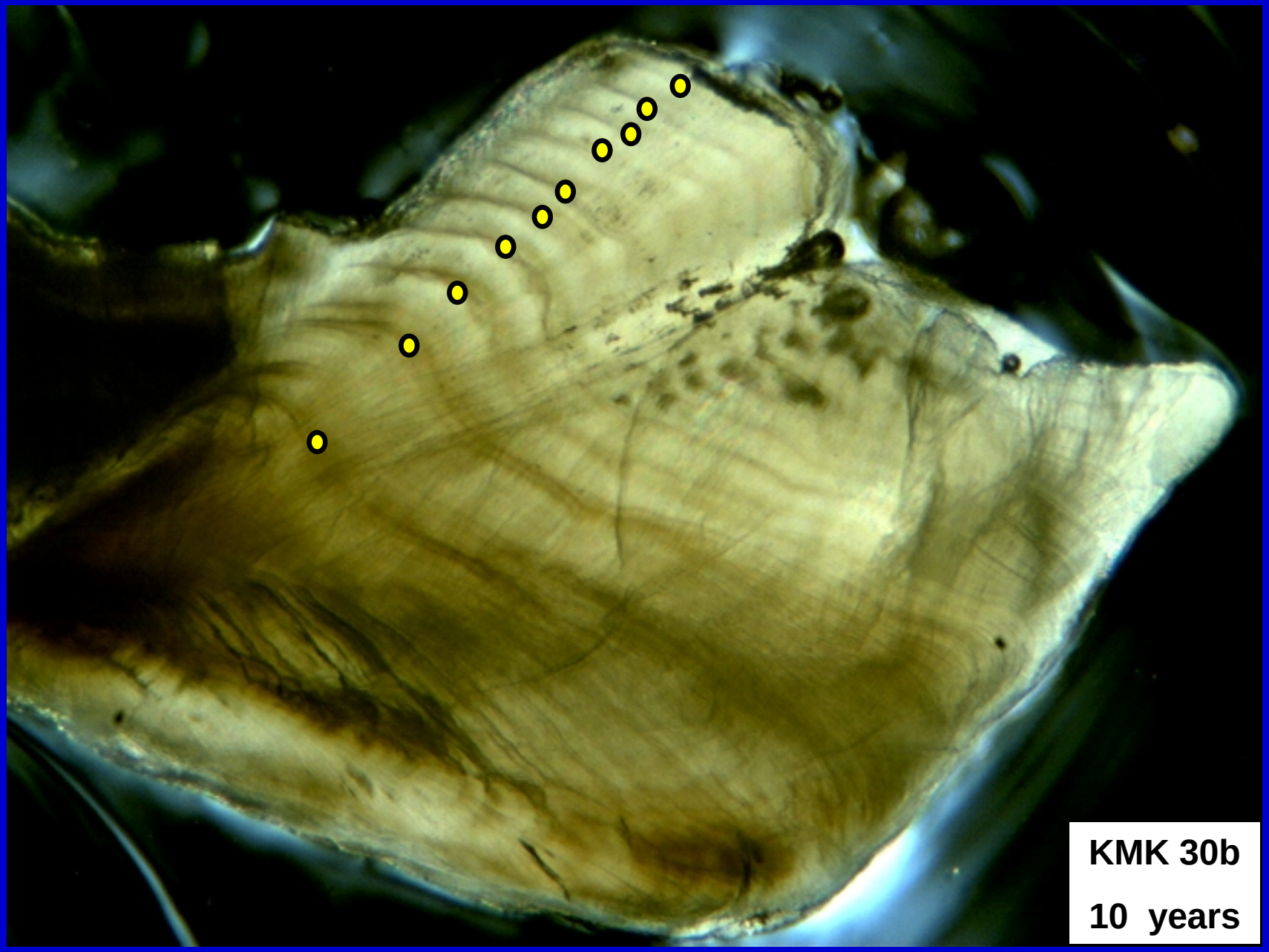

13
KMK 25b
13 years


KMK 26b
6 years


KMK 27a
5 years


KMK 28c
20 years


KMK 29c
8 years


KMK 30b
10 years